THE

INDIAN FOREST RECORDS

VOLUME I

Published by Order of the Government of India

CALCUTTA
SUPERINTENDENT GOVERNMENT PRINTING, INDIA
1909

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VOL. I PART I

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A Note on the Lac Insect (Tachardia lacca), its Life History, Propagation and Collection

By E. P. STEBBING, F.L.S., F.Z.S., F.E.S.
Imperial Forest Zoologist

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Price Rs. 1-4-0 per Part. Price Rs. 5 per Vol. of 4 Parts

THE INDIAN FOREST RECORDS.

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Published on January 1908

Circular No. $\frac{3}{290-4}$, dated Calcutta, the 13th February 1907.

From—S. EARDLEY-WILMOT, Esq., Inspector-General of Forests to the Government of India,

To—The Chief Conservator of Forests, Burma.

The Chief Conservator of Forests, Central Provinces.

All Conservators of Forests (except those in Burma and Central Provinces).

The Deputy Conservator of Forests, Coorg.

The Deputy Conservator of Forests, Andamans.

The Deputy Conservator of Forests, North-West Frontier Province.

The Extra-Assistant Conservator of Forests, Baluchistan.

The Extra-Assistant Conservator of Forests, Ajmer.

All Officers of the Imperial Forest Research Institute and College.

I HAVE the honour to address you on the subject of the future publication of departmental literature comprising the results of investigations and research by members of the Imperial Forest Research Institute, and of other members of the Department, as well as of those who not being attached thereto possess information of value which they are desirous of permanently recording. In the past the pages of the *Indian Forester* provided the principal medium by which subjects of professional interest were brought to the notice of a limited public, and in 1892 the "Appendix Series" to the *Indian Forester* was ocmmenced with the design of placing at the disposal of members of the Forest Department and others monographs on important subjects published at Government expense and circulated free of cost with the departmental magazine. In 1905 the Appendix Series gave way to Forest Bulletins, and since then 9 Bulletins (which have had a much wider circulation and have, judging from the demand, supplied a much-felt want) have been issued.

2. With the constitution of a Forest Research Institute and the development of scientific investigation in the Forest Department the necessity of placing Indian forest literature on a more satisfactory footing has become apparent and the Government of India have sanctioned a proposal that the same methods as have proved so successful in the Geological Survey Department should be adopted in the Forest Department so that publications containing important information may remain available for permanent reference and be issued in such form as would be most acceptable to the scientific world and most convenient for economic purposes.

3. In future therefore the pages of the (1) Indian Forest Records and of the (2) Indian Forest Memoirs will be open to those who desire to secure for their research and investigation a permanent place in Indian forest literature whence it will be available to all those interested in the science of Forestry. Forest Bulletins will no longer be issued and the following procedure will be observed in regard to the preparation and issue of Records and Memoirs which it is hoped will be effective in making the new departure the sueeess which it should attain with the wealth of material available :—

(1) *Indian Forest Records.*

(i) The Records will be printed on a page $9\frac{3}{4}'' \times 7\frac{1}{2}''$, and will consist of approximately 60 to 70 pages per Part. Each Part will be illustrated by reproduction from photographs or negatives, either as wood blocks (for simple line drawings), or by the lithographic, half-tone or collotype processes.

(ii) No definite date for the issue of the various Parts of the Records would be fixed, since no satisfactory objects appear to be gained by rigidly adhering to a monthly, quarterly or any other period. The advantages of a hard-and-fast date of publication would seem to be more than counterbalanced by the disadvantages which might accrue either from publishing a Part made up with inadequate materials owing to the fact that sufficient papers are not available, or from keeping back important papers and notes for several months to fulfil unnecessary stipulations imposed by a publishing time limit.

(iii) Four Parts would conveniently form a volume of the Records which will then be bound up with title page, etc.

(iv) The Records will be devoted to the publication of papers giving the results of the loeal investigations of the Research Institute staff, or of others whether members of the Department or not, together with any short notes on preliminary research, the publication of which may be considered of advantage to aid others in carrying out further observations in the subject under enquiry. Notes and observations supplied by Forest officers on such matters as the effects of exceptional seasons on forest growth, the seeding of the valuable species

of trees, sudden attacks of serious pests, etc., will find place in the Records.

(v) The Records will deal strictly with professional matters and should form a valuable current exposition of the work of the Department which will be of interest and utility alike to the members of the service and to scientists and those interested in Forestry throughout the world.

(2) *Indian Forest Memoirs.*

(i) The Memoirs will be published in quarto size, $12\frac{1}{4}'' \times 10''$, the size used by the Royal Asiatic and other Societies and by the Geological Survey of India, etc. The use of the quarto appears to be advisable as it allows, where necessary, of full-sized reproduction or of the preparation of a plate upon a scale commensurate with the requirements of the author. The Memoirs will be illustrated and the process of reproduction will be similar to those used in the Records save that the photogravure process will be also resorted to, where necessary.

(ii) Each issue will consist of one, two or more Memoirs or monographs. The Memoirs will be bound up into volumes of about 300 pages, excluding plates. A title page for the whole volume and one for each of the Memoirs it contains will be prepared and inserted before the volume is issued. Each Memoir will be separately paged at the top, the entire volume being paged at the bottom, the number being placed in square brackets.

(iii) The Memoirs will appear only when suitable monographs for reproduction in this form are received. They will be devoted to the publication of complete and important monographs on particular subjects. For example, Memoirs dealing with careful research made into the silviculture of a particular species of tree or with a family or genus of insect or fungus pests or the description of new species; researches into the formation, growth and economic uses of a particular gum, dye, tannin, etc.

(iv) The Memoirs will be kept strictly technical, and will be open to the papers of all authors having a scientific or economic bearing upon Indian Forestry.

4. For the present and until the new system of publication is placed on a satisfactory footing all papers and illustrations intended for insertion in the Records and Memoirs should be sent to the Inspector-General of Forests at Calcutta whence proofs will be forwarded to the authors before publication.

No. $\frac{248}{290-4}$.

Copy forwarded to the Government of India, Department of Revenue and Agriculture, for information.

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THE INDIAN FOREST RECORDS.

Vol. I 1907 **Part I**

A Note on the Lac Insect (Tachardia lacca), its Life History, * Propagation and Collection.

By E. P. STEBBING, F.L.S., F.Z.S., F.E.S.
Imperial Forest Zoologist

INTRODUCTION.

CONSIDERABLE attention has of late been paid to the subject of lac owing to the great value of the exports of this product as compared with the small forest revenue realized from the source. The total value of the export of lac from Indian maritime ports during the year 1905-06 reached the amazing sum of 3,31,39,786 or nearly $3\frac{1}{3}$ crores of rupees. The attention focussed on lac as an article of commerce has resulted in questions being raised as to the possibility of improving the quality of the article by the adoption of better methods of collection. The examination of these methods has led naturally to enquiries as to the manner in which the lac is formed and as to the best periods, from a mercantile point of view, at which it should be collected. Such queries go at once home to the root of the whole matter: into the method of formation or deposition of the material known as 'lac' upon the twigs of the trees upon which it is found and the manner in which it is collected from the trees and sent to the factory.

That lac is the product of an insect is now well known, but considerable ignorance exists as to the manner in which it is produced. To understand this latter a thorough acquaintance with the life history of the insect is indispensable. It is one of the objects of this note to describe in a simple manner the various stages in the life of this valuable scale and to suggest measures by which its cultivation and collection may be both increased and improved. Its distribution and abundance in the different parts of the country will also be dealt with.

CHAPTER I.

ORIGIN AND NATURE OF LAC.

Lac is a resinous incrustation excreted by a scale insect known as *Tachardia lacca.* The mouth parts of this insect consist of a 'beak' or sucking apparatus combined with a pointed lancet. With this latter the scale pierces the bark of the twig of the tree and then inserts the sucking tube and draws up the sap. The insect may be likened to an animated siphon, since the sap continually sucked up through the beak is, after modification and absorption of some of its products, given out as an excretion at the anal end of the body. This excretion solidifies on contact with the air and thus there is gradually formed round the body a 'scale' or 'cell'. This scale or cell is popularly known as lac. Were only a single insect present on a branch the scale would appear as a circular dome-shaped reddish excrescence on the surface of the bark. Owing, however, to the production by the female of a very large number of eggs (as many as 1,000) and the habit of the insects, which indeed is common to many of the family, of living and feeding gregariously closely packed together on one twig, the scales or cells coalesce during their formation and result in the production of a continuous incrustation on the twigs which, on collection, forms the article of commerce known as stick-lac. From this stick-lac the product known as 'shellac' is manufactured. There is a second substance obtainable from the scales and known to commerce as lac-dye for which formerly there was a considerable demand—a demand which, owing to the introduction of synthetic dyes, has practically disappeared. As will be shown later, this product consists for the most part of the material from which the eggs are developed in the body of the female insect. There is still a small export of this lac-dye from India, but as will be seen from the table at the end of this monograph (Chapter XV) the total value for the whole of India is extremely small.

CHAPTER II.

HISTORICAL.

The lac industry is amongst the most ancient of the minor industries of India. The trees *par excellence* upon which the insect lives are the

Kusum (Schleichera trijuga) and the *Palas* tree (Butea frondosa), the latter of which is known in Sanskrit literature by the name of Lakhsa-taru or lac-tree. The aboriginal tribes throughout India recognise the *Palas* tree as *the* lac-tree, and the industry would seem to have an antiquity of several thousand years in the country.

In ancient times, as at present, the resinous material or shellac was more valued in India than the lac-dye. It was the latter, however, which was first exported to Europe.

That the lac-resin was used as a varnish some centuries ago is evidenced by the fact that in the Ain-i-Akbari issued by the great Akbar in 1590, a note is given on the subject of the proportions of the resin to be employed in the varnishes used for the wood work of public buildings.

One of the earliest European writers on the subject of lac was a Dutchman sent to India on a scientific mission by the King of Portugal. His explorations were published in 1596, an English edition issuing in 1598. He gives full particulars as to the uses of the resin, but shows that he was totally ignorant as to the agency by which the substance was formed.*

CHAPTER III.

THE GROWTH OF THE INDUSTRY.

The cultivation and collection of lac was, and practically still is, chiefly in the hands of the aboriginal races of the poorer parts of the country, and the methods of propagation and collection still in force are those which were in existence centuries ago. These methods satisfied the demand for the article in the country and, until quite recently, that of the export trade. This latter has developed but slowly. It took nearly half a century for the properties of the resin to be fully appreciated in Europe. As we have seen, it was the dye which first made its appearance in Europe, and its export was long limited by the difficulty experienced in extracting the colouring matter and applying it to manufactures at home. At first the value of the export was about two lakhs from which it fell to less than one lakh. In 1820-21 it again rose, and in 1824-25 its value exceeded seven lakhs. Its great competitor was cochineal, for which it was used as a substitute.

**Asiatic Journal*, 1831, p. 220.

At the beginning of the century the exports of lac-dye from India were five to six times more valuable than those of the resin. As showing the progress of the export industry and the growing demand for shellac and decrease in utility of lac-dye between 1868 and 1900 the value of the exports of the former increased from Rs. 18,41,491 to Rs. 92,65,600, whilst that of the latter decreased from Rs. 4,45,612 to *nil*.

CHAPTER IV.

THE LAC INSECT.

I. CLASSIFICATION.

Classification.
Order—Hemiptera.

The lac insect belongs to the great order of insects known as the *Hemiptera* or Bugs, Plant lice and Scale insects. The most important characteristic of the members of this order is that the insects are furnished with mouth parts in the form of a piercing and sucking beak or proboscis. The greater number feed upon the sap of plants, piercing through the outer layers of the stem and burying the proboscis in the succulent sappy layers beneath. The lac insect belongs to the family *Coccidæ* or scale insects, as they are commonly known.

Family—Coccidæ.

2. POSITION AMONGST SCALE INSECTS.

Position amongst scale insects.

The *Coccidæ* may be roughly divided according to the mode of life of the species into two great groups:

(*a*) Those insects which move about during the whole of their life and do not form 'scales';

(*b*) Those insects which, although active during a portion of the young or larval stage of their existence, sooner or later come to rest on the food plant, bury their proboscis in the succulent inner bark of the twigs of the plant and gradually build up by excretions a covering or 'scale' round themselves, which may eventually completely enclose the insect.

It is with the second of these two divisions that we are concerned here.

3. Reason for Production of Scale.

Reason for the production of the scale.

The reason for the production of these scales is probably primarily protective. As long as the insect keeps moving about it is not so completely at the mercy of predaceous foes such as birds and insects as is the case the moment it comes to rest and buries its proboscis in the layers of the twig. From this time onwards the lac scale, like all scale insects which have the same habit, becomes completely at the mercy of all its foes. The production of a scale or covering which gradually encloses the insect removes this danger.

4. Description of the Lac Scale Insect.

Description.

As has been already stated lac is a resinous incrustation produced upon the twigs of certain species of trees by the insect known as *Tachardia lacca* or the lac insect. The lac originates as an excretion, exuded by the scale from the anal orifice, which gradually accumulates around and encloses the insect beneath a shell-like covering.

The young or larval stage and the mature female and male stages of the insect are described below. Pl. I, fig. 1, shows a much-magnified collection of empty egg skins from which the larvæ have escaped.

Larva.

Larva.—The newly hatched insect or *larva* is a minute red or orange coloured insect, elliptical in shape, rather obtuse in front and more constricted towards the lower extremity. There is no obvious constriction between the head and body in front. The head has two small marginal eyes and two short antennæ or feelers. There are six short legs on the body which consist of nine segments ; on the penultimate segment there are two very long hairs. There are two tufts of white powdery, hair-like filaments growing from the sides of the thorax (the segments following the head) respectively, in the place of wings, and a tuft of the same kind, bifurcating and curling outwards on each side, projecting from the anal orifice. The length is $\frac{1}{40}$th of an inch. It is impossible to distinguish any distinction of sex at this stage of life. Pl. I, figs. 1 *a*, 1 *b*, depict the side and dorsal view of the male larva enlarged and 1 *e*, the enlarged antenna, and figs. 1 *c*, 1 *d*, the same of the female insect, with 1 *f*, the enlarged antenna.

Female.

Female insect.—By the end of a month the female insect has become considerably swollen and enlarged, having excreted a certain amount of a resinous scale substance (lac) round it. It is then $\frac{1}{18}$th of an inch in length. By now it will be seen that the antennæ, legs and the head (chitinous) outer portions of the body have disappeared, having become incorporated with the resinous secretion. The eyes have disappeared, and if the resin is dissolved away from the insect it wil be seen to have become a dark-red, elliptical, smooth, shining sac, the only appendages visible being the three white tufts or hair-like filaments at its obtuser end and the beak or proboscis at the elongated end, which is now fully developed. The proboscis consists of a fleshy projecton situated beneath the insect at a short distance from the head. This structure consists of several hairs and spines which together form the penetrating organ by which the bark is pierced and the tube up through which the sap is sucked into the body. The three apertures from which the white tufts proceed and which can now be seen to open through the resinous incrustation are situated at the thoracic and posterior ends of the insect. The two former appear to replace the wings whilst the latter proceeds from the anal aperture. The white tufts projecting from these consist of the extremities of the tracheæ (the air tubes which ramify through the body of an insect and form the air-breathing apparatus are termed tracheæ) and are covered with a white powder.

Thus the increase in size which takes place in the female insect, from the locomotive or active walking stage possessed by the young larva to the subsequent quiescent motionless stage of life, is chiefly brought about by an enlargement and elongation of the body between the mouth and the parts of the body from which the three white tufts project.

The chief points of interest in the interior of the body are the irregularly massed bundles, without any apparent order, of the white tracheæ, many of whose extremities protrude through the three apertures (two small thoracic and one large anal) on the surface, as described above, and the ovary. This ovary is of immense size, almost filling the body and contains the red colouring matter known as the lac-dye of commerce.

Pl. II, fig. 1 *d*, shows the empty skin of the female insect after the larvæ have issued from it.

The scale which covers the female insect at this stage is, when isolated from the rest (which is not often the case as they are usually agglomerated

into a mass), seen to be circular with twelve notches arranged round the base, six on each side. The outer surface is covered with a kind of white powder which is concentrated here and there into little spots. being chiefly confined to the three white tufts which radiate from three small holes situated in the incrustation or scale. These holes are placed triangularly, two being closer together than the third, which is the anal and largest one, the others being spiracular orifices (breathing openings). These three openings are continuous with the three corresponding apertures described above as situated on the insect and from which the three white tufts protrude.

Male insect.

The male insect.—About two months after the small red larvæ first issue small red insects are to be found actively crawling over the newly formed incrustations of the females. These are the male insects.

The male is a little larger than the larva when it first issues ; it has larger antennæ which are hairy-plumose and consist of seven joints excluding the two basal ones ; there are four eyes, two lateral and two placed underneath the head ; two long hair-like appendages project from the upper side of the penultimate segment of the body ; on the last segment there is a beak-like horny process which is curved downwards and is connected with the generative organs. The changes undergone by the male larva in its development consist therefore of a slight increase in size, in a marked development of the antennæ, in a differentiation of the head and the addition of two large eyes beneath, whose function appears to be to enable the male to see the openings on the lac connecting with the female generative organs.

The male larvæ, as is the case with the female, after a short period of activity after first hatching, come to rest on the twig and bury their probosces in it. A scale is formed, but this differs from that of the female in being slightly smaller, narrower, and elliptical in shape and in having no serrated base or holes or white, hair-like appendages. This scale is open at its posterior or unfixed end and the male on maturing leaves it at this end by elevating it and crawling out backwards.

5. LIFE HISTORY.

(*a*) General.

Owing to the varied nature of the climate in India the life histories of most of the insects which are more or less universally distributed over the continent

differ to a greater or less extent according to the degrees of heat or moisture, or of both, experienced in the localities they inhabit. It will be necessary here, therefore, to give a general life history of the lac insect to begin with, subsequently detailing the variations in the number of broods, times of appearance, etc., appertaining to different parts of the continent.

The insect usually passes through two generations in the year, although there may, in some parts of the country, be a third. The periods at which the young larvæ are seen to swarm upon the trees are about the first week in July and again in the first week in December or even as late as January.

Commencing with the July generation the first of the minute red larvæ swarm out of the dried-up shelly incrustation about the beginning of the month and spread over the neighbouring twigs of the tree, these latter assuming a reddish colour owing to the countless numbers of living larvæ moving over them (*vide* Pl. II, figs. 1 and 1*a*). The larvæ do not all hatch out from the eggs at once, but apparently continue to emerge for as long as a month after they first appear. One effect of this is that it ensures some of the young ones living should the weather prove inclement during the hatching out of any portion of the brood. The larva on leaving the incrustation crawls on to a neighbouring twig and searches for a suitable soft sappy part, and then, piercing through the cortex, buries its proboscis in the tissues and comes to rest in this position. During the search for favourable situations large numbers of the young grubs die, either through being unable to travel the necessary distance to find a suitable twig to feed upon, or owing to their inability to pierce the cortex and insert their proboscis to obtain nourishment.

As soon as the larva has come to rest it commences to suck up the sap of the tree and exude a substance which, drying round it on contact with the air, gradually forms a cellular structure which is either circular or ovoid in shape. Pl. II, figs. 1 *b* and 1 *e*, show transverse and longitudinal sections of lac cells. The former are the female incrustations and are larger than the latter, which are the males. Owing to the habit of the young grubs in swarming in large numbers together and fixing themselves to twigs in close adjuxtaposition, the cells, as they undergo enlargement, gradually coalesce and thus produce the well-known thick incrustation on the branches which is commonly known as lac (*vide* figs. 1, 1*a*). During the growth in size of the female incrustations or cells, which are the most numerous, structural changes are taking place

in the larva and this latter is gradually becoming matured into the female insect.

Some two and a half months after the period of swarming of the larvæ the male insects mature and leave the cell by pushing up the lower edge and crawling out backwards. These male insects on getting free crawl over the lac incrustation and impregnate the females through the anal opening already described. After pairing the male dies. After impregnation further changes take place in the female; the ovary becomes greatly enlarged, occupying the greater part of the body, and becomes filled with a bright red fluid in which the eggs are formed. It has been estimated that each female bears as many as 1,000 eggs, and as these become mature the mother dies, consisting at that period of little more than a skin. This dries and shrivels up after the young larvæ have hatched. On hatching out the larvæ either issue through the anal orifice or through ruptures in the skin.

It is thus evident that as soon as the larvæ have left the shell the latter, *i.e.*, the lac incrustation, contains no further insects, and incidentally it may be mentioned that it also contains a much smaller amount of colouring matter.

This life cycle is repeated at least once more during the year, and in some places twice.

The larvæ of the first brood of the year swarm at the beginning of July, the females being impregnated towards the middle of September.

The larvæ of the second brood of the year swarm from the beginning of December to the beginning of January, the males, which in this brood have wings, impregnating the females about the middle of February to March.

The production of a winged male generation in February is doubtless to ensure a complete impregnation of the females on trees where males are scarce. The insect is probably spread from tree to tree by wind, birds, and insects, since the larvæ are so minute and light as to be easily blown or carried about.

Since the above was set up in type the following valuable notes on the life history of the insect in the Raipur Forests of the Central Provinces has been drawn up from careful personal observations by Mr. A. Lowrie, Deputy Conservator of Forests, and Mr. Dhanji Shaw Nasarwanji Avasia, Extra Assistant Conservator of Forests, Central Provinces.

The Report is as follows :—

Note on the life hi tory of the lac in connection with questions suggested by the Inspector General of Forests for investigation.

i. The period that elapses between the swarming of each brood and their attachment to twigs extends to not more than 12 hours. From observation it was found that the larvæ from cells attached to a twig do not all swarm out at one and the same time, but that the swarming goes on for about 20 days. Directly the larvæ swarm, they move about in search of food and if fortunate soon attach themselves to twigs ; others less fortunate die in numbers in their endeavours to find a suitable attachment and food.

Period between swarming and attachment.

ii. (*a*) It does not acclimatize itself by moving about the lac during the day and returning to the cell at night. The idea that led to this statement was due to the very few insects observed as evening set in ; this was found to be due to numbers swarming out in the early morning and moving off the lac or being blown off it by the wind. The swarming generally takes place very early in the morning, especially on a good sunny one.

Swarming takes place early in morning.

(*b*) The insect, while moving about, and in search of an attachment and food, does not feed on anything.

No food till attachment.

iii. (*a*) The lac-exudation begins directly after attachment, though the larvæ are not themselves completely covered over; this is probably done to protect itself against the weather. This first incrustation is so very fine that it is not noticeab'e with the naked eye. It goes on increasing very slowly.

Secretion when begun.

(*b*) After a period of three months the insect is completely covered over with the incrustation.

Period of entire covering of insect with incrustation.

iv. (*a*) Impregnation takes place after a period of two and a half months from the time of attachment of the insect.

Impregnation when performed.

(*b*) The insect then goes on increasing slowly for another three and a half months when the new brood appears.

Period between impregnation and swarming of new brood.

v. For about two and a half months of the above period of three and a half months the female insect is employed in exuding the lac incrustation and developing in the ovaries the red colouring matter.

Insect how employed after.

The last month is evidently a period of rest and during this time from all appearances it lies dormant and abstains from food. This was found to be the case by removing the "dal" lac from the twigs; that removed a month before the actual time of swarming on the trees and carefully kept, gave a brood of insects at the same time as the seed-lac left on the trees.

Last period of existence of female.

How found

(*a*) In five months the female has arrived at maturity and during the whole of this time she is deriving sustenance from the twig to which she attached herself.

Time taken by female to reach maturity.

(*b*), (*e*), (*f*). The lac exudation as it is formed round the female is viscid and this gradually hardens on exposure to the weather; but before the hardening has quite taken place the female, to allow for her growth, pushes the incrustation outwards radially, leaving a fine partition between the cells and thus avoiding any undue pressure.

Nature of secretion.

vi. After impregnation the red fluid is formed in the anal or ovary sac of the female; it consists at first of a thin fluid colouring matter and within this the ovaries float and are matured until the dormant period of the last month. About this time the ovaries have reached maturity

Fluid in ovary sac and its nature.

and the red fluid begins to thicken, this process reaches the final stage when the ovaries are quite ripe and the larvæ swarm out of them. The sac is then quite loose and consists of an outer covering with a few grains of a red powder within it. The female having performed her functions dies as soon as the larvæ begin to swarm.

(*b*) Life history in different parts of the country.

It has been said that the life history varies in different parts of India.

In Sind the first crop of lac is collected from April to June and the cold weather crop from November to January. In the Punjab the crops are gathered in April-May and October-November. In the United Provinces the periods are July and October about Rurki, and April-May and October-November in Bundelkhand.

In the Central Provinces the crops are gathered in June and from 15th December to the 15th February. In Bengal April to July, and October-November are the periods in Palamau ; in Birbhum the times of collection are the middle of March to May (this being the best crop) and middle of August to October. In Assam there are two crops collected in May-June and October-November, respectively, the latter being the chief export crop. In Upper Burma the collection of lac is said to take place from May to November, but the quality is poor until August. There are said to be three generations in the year in Burma.

CHAPTER V.

THE FOOD PLANTS.

The trees *par excellence* which form the commonest hosts of the lac insect are the *Kusum* (Schleichera trijuga) and the common *Palas* or Dhak tree (*Butea frondosa*) of India. The insect feeds, however, upon many other trees, particular species being chiefly valued for propagating and rearing the insect in the different areas of production in the country.

The following table has been compiled to show the principal trees

upon which the lac insect feeds with the localities in which they grow and the quality of the lac produced upon the different species :—

LAC-YIELDING TREES.

[*N.B*—The most important and valuable lac-yielding trees are printed in capitals.]

Name of tree.	Vernacular names.	Localities in which the lac insect feeds upon the tree or trees.	Abundance of lac produced.	Quality of lac produced.
1. Acacia arabica .	*Babul, Kikar*	Sind, Rajputana, Guzerat, Punjab, Berar.	Yields large quantities of lac.	
2. Acacia Catechu .	*Khair* . .	United Provinces, Central Provinces.		
3. Albizzia Lebbek	*Sirus, Siris, Siras.*	Punjab, Sind, Bombay, United Provinces, Upper Burma.		
4. Albizzia lebbekoides.	..	Burma.		
5. Albizzia lucida .	*Silkori* .	Bengal.		
6. Aleurites moluccana.	*Akrot* . .	Punjab.		
7. Anona squamosa	*Ata* . .	Punjab, Lower Burma.		
8. Artocarpus integrifolia.	..	Burma.		
9. Bauhinia sp. .	..	Do.		
10. BUTEA FRONDOSA.	*Dhak, Palas, Khankar, Pankbin Khakhra, Chiulha, Muru.*	Sind, Bengal, Berar, Punjab, Central Provinces, Central India, Rajputana, portions of the United Provinces, South India and Burma.	Yields large quantities of lac, especially in the United Provinces, Central Provinces and Bengal.	The lac produced on this tree is second only to that of the Schleichera trijuga.

LAC-YIELDING TREES—*contd.*

Name of tree.	Vernacular names.	Localities in which the lac insect feeds upon the tree or trees.	Abundance of lac produced.	Quality of lac produced.
11. Butea scandens	..	Bengal.		
12. Butea superba	..	Chota Nagpur, Central Provinces, Berar.		
13. CAJANUS INDICUS.	*Arhardal, Arhar, Mirimah Garomah.*	Northern Bengal, Assam.	Yields lac in large quantities.	Yields the finest lac in Assam.
14. Careya arborea	..	Travancore.	Sparingly.	
15. Carissa Carandas.	..	Punjab.		
16. Cassia siamea .	..	Burma.		
17. Castanopsis sp.	..	Do.		
18. Celtis Roxburghii.	..	Punjab, Eastern Bengal, Central India, South India.		
19. Ceratonia Siliqua.	Carob tree .	Punjab, South India.		
20. Cordia Myxa .	*Lasura* .	Punjab		
21. Croton aromaticus.	..	..		
22. Croton oblongifolius.*	..	Burma.		
23. Dalbergia cultrata.	*Yindaik*	Do.		
24. Dalbergia latifolia.	*Shisham* .	Do.		
25. Dalbergia paniculata.	*Dhobeyne* .	Central Provinces, Berar.		
26. Dalbergia Oliveri.	*Tamalan* .	Burma.		

* Yields the medicinal lac of Ceylon.

LAC-YIELDING TREES—*contd.*

Name of tree.	Vernacular names.	Localities in which the lac insect feeds upon the tree or trees.	Abundance of lac produced.	Quality of lac produced.
27. Dalbergia ovata	..	Burma.		
28. Dichrostachys cinerea.	*Virtuli* .	Central India, South India.		
29. Dipterocarpus tuberculatus.	*Ingyin* .	Burma.		
30. Dolichandrone Rheedii.	..	Burma, Andaman Islands.		
31. Echinocarpus assamica.	*Joba* . .	Assam.		
32. Eriolæna Hookeriana.	*Butea* . .	Central Provinces.		
33. Erythrina indica.	..	Punjab.		
34. Feronia Elephantum.	..	Do.	Yields lac.	
35. Ficus alternarine.	..	Assam.		
36. Ficus altissima	*Bars, Domaru, Kathali bat*	Do.		
37 FICUS BENGALENSIS.	Banyan tree, *Barh, Barghat, Bargad.*	Sind, Rajputana, Punjab, United Provinces, Berar, Central Provinces.		
38. Ficus Carica .	*Arijer* . .	Punjab.		
39. Ficus comosa .	*Juri pakari* .	Assam.		
40. Ficus cordifolia	Pair, Pakari	Bombay, Sind, Assam.		
41. Ficus Cunia .	*Poro, Gular* .	Punjab, Bengal.		
42. Ficus elastica .	Indian rubber tree, Bar.	Assam.		

LAC-YIELDING TREES—*contd.*

Name of tree.	Vernacular names.	Localities in which the lac insect feeds upon the tree or trees.	Abundance of lac produced.	Quality of lac produced.
43. Ficus glomerata .	*Gular, Guler* .	Punjab, United Provinces, Central Provinces.		
44. Ficus infectoria	*Pakar, Acol* .	United Provinces, Central Provinces, Bengal, Assam.	Frequently bears lac.	
45. Ficus laccifera	*Ruthal But* .	Sylhet.		
46. Ficus nervosa .	...	Burma.		
47. Ficus obtusifolia	...	Do.		
48. Ficus palmata .	*Phagura* .	Punjab.		
49. FICUS RELIGIOSA.	*Ashwat, Ahat,* Pipal, *Pipla,* Pipar, *hesa.*	Most provinces and in Travancore.		The lac on the pipal tree differs from that of other trees in being paler in colour and in having a larger grain.
50. FICUS RUMPHII.	*Jhuri, Asvatha, Jariahat, pakori.*	Assam.	Is an important lac-yielding tree.	
51. Ficus Tjakela .	*Pilkhan, Pakhar.*	Punjab, Central Provinces.		
52. Flemingia congesta.	*Makhitoli* .	Assam.		
53. Garuga pinnata	*Garuja, Kaikar.*	Burma.		
54. Glochidion sp.	...	Do.		
55. Grewia lævigata	...	Assam.		
56. Grewia tibæfolia	..	Berar		
57. Jamiferus macropoda	Nhuh . .	Assam		

LAC-YIELDING TREES—*contd.*

Name of tree.	Vernacular names.	Localities in which the lac insect feeds upon the tree or trees.	Abundance of lac produced.	Quality of lac produced.
58. Kydia calycina	*Pola, Barranga*	Bengal, Central Provinces.		
59. Lagerstrœmia parviflora.	*Bakli, Leudya Sida.*	..		
60. Mangifera indica	Mango .	..	In its wild state the mango often yields lac.	
61. Nephelium Litchi.	Lichi . .	..		
62. Odina Wodier .	..	Travancore.	Sparingly.	
63. Ougeinia dalbergioides.	*Sandan, Tinsa, Tiwas.*	Sind, Central Provinces, Berar.		
64. Prosopis spicigera.	*Jhand*, Kandi	Punjab, Bombay, Sind, Guzerat.		
65. Pentacme siamensis.	*Ingyin* .	Burma.		
66. Pentacme suavis	..	Do.		
67. Pterocarpus Marsupium.	*Kino, Bija*	Central India, South India.		
68. Pithecolobium bigeminum.	*Maj* . .	Assam.		
69. Pithecolobium dulce.	*Dakhini Babul*	..		
70. Pithecolobium Saman.	..	Burma.		
71. Schima crenata	..	Do.		
72. SCHLEICHERA TRIJUGA.	Kusam, Kusamb baru.	Sub-Himalaya, Central India, South India, Burma.	The most important of all the lac-bearing trees.	Yields the finest lac.
73. Shorea obtusa .	..	Burma.		

LAC-YIELDING TREES—*contd.*

Name of tree.	Vernacular names.	Localities in which the lac insect feeds upon the tree or trees.	Abundance of lac produced.	Quality of lac produced.
74. Shorea robusta	*Sal* . .	United Provinces, Submontane regions, Oudh, Central Provinces, Bengal, Assam, North Madras.	An excellent tree for lac cultivation owing to its good coppicing powers. It is too good a timber tree however to be ordinarily used in this manner.	
75. Shorea siamensis.	..	Burma.	..	
76 Shorea Talura .	*Jala* .	Mysore, Coimbatore Hills.	This is the most important lac tree of Mysore.	
77. Spatholobus Roxburghii.	..	Bengal, Travancore.	.	
78. Stereospermum fimbriatum.	..	Burma.		
79. Streblus asper	..	Do.		
80. Tamarindus indica	..	Do		
81. Tamarix gallica	Tamarisk .	Sind.		
82. Tectona grandis	Teak, *Sagon*	Central India South India, Burma		
83. Thespesia Carr	*Bonka pahi* .	Assam.		
84. Terminalia tomentosa.	*Saj, Piasal, Asan, Ain.*	Chota Nagpur, Central Provinces, Berar, Burma.		
85. Xylia dolabriformis.	*Jamb* . .	Burma.		

LAC-YIELDING TREES—*concld.*

Name of tree.	Vernacular names.	Localities in which the lac insect feeds upon the tree or trees.	Abundance of lac produced.	Quality of lac produced.
86. ZIZYPHUS JUJUBA.	*Ber, Bar, Kul, Bogori Bhor Bordi Bair, jamun*	Bombay, Sind, Central India, Punjab, United Provinces, Central Provinces, Berar, Bengal, Rajputana, Assam, Burma.	A good lac-bearing tree owing to the ease with which the insect can be propagated upon it and is therefore largely used in the cultivation of insect.	The lac is inferior in quality to that produced on some other trees.
87. Zizyphus xylopyra.	*Kat-ber, Ghonti, Ghat-ber.*	Central Provinces, Berar, United Provinces.		

CHAPTER VI.

INJURY DONE BY THE LAC INSECT TO THE TREES.

Most scale insects must be looked upon as injurious pests to the trees upon which they live since they tap the plants of their sap in varying amounts. The lac insect is no exception to the rule, although it is probable that its numerous hosts are affected in a varying degree by its attacks. It stands to reason that a steady drain upon the sap of small twigs by what may be termed so many animated siphons must result in the twigs eventually dying and drying up and this is what actually occurs. It is probably but rarely, however, and that only in the case of certain species of tree, that the latter are ever killed by the insect. Mr. J. McKee, Conservator of Forests, called attention to this subject in his valuable report* on the subject and suggested that Forest Officers should make a study of this point with a view to enabling a proper system of pruning the trees to be introduced in areas of lac cultivation. This point will be returned to when considering the question of the propagation and cultivation of the insect.

* *Indian Forester*, Vol. I, p. 26.

CHAPTER VII.

ENEMIES OF LAC.

The lac insect has to contend against enemies of various kinds, the chief among which are animals, insects, fungi, natural influences, forest fires, and man.

(a) Animals.

Both birds and monkeys prey upon the lac insect. The former feed upon the young larvæ when swarming and after they have come to rest upon the twigs and before the shell-covering has formed to shelter them. Monkeys feed upon the sweet incrustation.

(b) Insects.

These are of two kinds.

(1) Insects not directly predaceous upon the lac insect

Ants of various species swarm upon the lac incrustations to lick up the sweet excrement exuded by the insect. They do not prey upon or feed upon the insect itself, but often nip off the ends of the white filaments, doubtless merely with the object of getting them out of the way. Since the two anterior of these are in connection with the respiratory apparatus of the lac insect the latter is killed, the completion of the cell is stopped, and no eggs are laid by the insect.* When ants infest the lac-bearing

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* Since writing the above Mr. E. R. Stevens, Deputy Conservator, Kumaun Division, United Provinces, has forwarded the following account of the depredations of a black ant, identified as *Camponotus compressus*, Fabr., on young lac larvæ.

The information was furnished by Ranger P. Shambhoo Dutt Joshi and is as follows:—

'I am sorry to report that ants (specimens enclosed) have appeared on the Arhor plants at Chorgalia and have eaten all the lac insects together with the little lac already prepared by them. The ants, I hear, always appear on lac plantations and especially do much damage with easterly winds.'

Mr. Stevens wrote:—'A field of Arhor of 1 acre 30 poles was sown in November 1906 and about one-third of the area was infected this year with seedlac on the 10th July when the Arhor was about 2 feet high. The insects swarmed well from the seed lac and the formation of new lac was progressing satisfactorily when the present plague of black ants ruined the whole experiment.'

It having been pointed out that present observations seemed to show that ants did not actually eat the insect but only cut the respiratory filaments whilst sucking

branches the lac never appears to be so healthy and many of the cells will be found to contain dead insects. Ants should therefore be kept off lac-bearing trees.

(2) Insects directly predaceous upon the lac insect.

Very little is known about the species of insects which prey upon the lac insect. As far as is at present known, the lac is attacked by one or more caterpillars belonging to species of *Galleria* and *Enblemma*.

In 1899-1900 Mr. D. O. Witt, of the Indian Forest Service, made some interesting investigations into the life history of a species of *Enblemma* subsequently identified as *E. amabalis*. Mr. Witt wrote an interesting paper to the *Indian Forester* which deals so fully with the subject that it is reproduced below. The following are descriptions of the caterpillar and moth :—

Larva.—Small, white, without markings. Head darker coloured. Pl. I, fig. 2, shows this larva enlarged.

Pupa.—Small, narrow, palish yellow. Length $\frac{1}{4}$ inch. The pupa is enclosed in a cocoon made of particles of lac, and figs. 2 *a* and 2 *b* show the pupa and cocoon.

Moth.—Ochreous white in colour. The fore wing with a brown transverse angled line near the middle, the portion beyond it being pink, except at the costa. The hind wing with the base pale, with an indistinct brown transverse line. Both wings with submarginal whitish lines with pink beyond them. Expanse of wings 24 millim. Pl. I, figs. 2*c*, 2*d*, show the male and female moths.

Mr. Witt's note is as follows :—

" There are two crops of lac each year formed by the young larvæ of *Tachardia lacca*, the first swarming out in July and the second in

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up the sweet excretions, thus ensuring the death of the insects beneath the scales, the Ranger subsequently wrote as follows on this point :—

'A few days after the lac was laid to the Arhor plants, the lac insects swarmed out and in about a week they began the process of making lac on the Arhor plants. Just at that time hundreds of the ants appeared and surrounded the place where the lac was being made and as far as I could examine I found them eating both the sweet exudation and the lac insects themselves.'

This point is one of such importance as well as of considerable interest that it requires early and close investigation. It is not inconceivable that the ants may pierce the soft bodies of the young larvæ with their mandibles with the object of sucking out the sweet secretion with which they are filled. Aphidæ (plant lice) are provided with a pair of small siphon-like bodies on the dorsal surface of the body; by exerting pressure on the sides of the body by means of their antennæ small drops of the sugary secretion are emitted from the siphons and sucked up by the ants. The lac larvæ are unprovided with such siphons and it is probable that the pressure exerted upon the bodies to cause them to exude the sweet secretion results in ruptures of the thin skin and subsequent death.

November. The lac in which the larvæ of *Enblemma amabalis* were found was that produced by the July brood. I first noticed the attacks on the 26th September and collected some of the larvæ. The larva is white and unmarked, the head only being dark. It appears to feed upon the soft bodies of the lac larvæ, taking up its abode with them beneath their resinous coating and forming a webbed covering connected with the outer air by a silken tube woven together with an admixture of reddish excreta. Whether the tube is formed just previous to pupation, as a tunnel of escape for the perfect insect, I am not aware. Mr. G. C. Dudgeon, F.E.S., of Palampur, Punjab, to whom I am indebted for the naming of the insect and to whom I sent specimens of the larvæ, perfect insect, and a specimen branch of the lac incrustation attacked by the larvæ of *E. amabalis*, is of opinion that these silk tubes are made as a tunnel of escape, as the tubes are all of the same size and therefore presumably formed by larvæ in the same stage of development; and portions of the pupa shell were found inside the resinous coating just beneath these tubes. On the other hand, I did not notice that these tubes were ruptured by the emergence of the perfect insect. Figs. 2, 2*a* show these tubes.

" Six imagoes of the larvæ which I collected early in November 1899 emerged between January 12th and 20th, 1900. Three more between January 22nd and 27th and two more on February 17th. It would appear, therefore, that one generation of the insect lasts about seven months as the lac incrustation only begins to form in August.

" Among the more interesting points requiring investigation with regard to *E. amabalis* I may mention the following in the hope that they may bring forth some information from other quarters :—

" (1) Does *E. amabalis* attack both crops of lac ? (So far I have only found it on the winter crop.)

" (2) Does it attack lac on trees other than Zizyphus xylopyra ?

"(3) How many generations of the insect are there in the year ? (There must surely be more than one, because the interval between January, when the imagoes emerged, and August, when the winter crop on which I found the larvæ commences to form, is unaccounted for.)

"(4) The eggs, their form, colour, etc., and where they are deposited."

I have since bred out moths of this species in Dehra Dun from lac received on *S. trijuga* from Raipur in the Central Provinces. Moths issued in the last week in March, the delay in appearance being accountable for by the much colder climate.

Remedies.—The question of protecting the lac insect against these pests is at present, owing to the insufficient information available, a difficult one.

For the ants the matter is, however, fairly simple. A ring of some sticky substance placed round the tree stems, wood ashes placed round their bases, or small heaps of some substance the ants would prefer to lac placed in the neighbourhood would all serve effectually to keep a check upon them.

When the predaceous enemies come to be considered the matter is much more difficult. Something can no doubt be done by taking precautions to avoid spreading the predaceous pests by taking care not to propagate lac from seriously infested trees. Lac-bearing branches required for propagation should on no account be cut from lac trees infested with the predaceous caterpillars. When the lac cells are seen to contain large numbers of these caterpillars on any particular tree or series of trees the whole of the lac-bearing branches should be cut off and burnt *at the periods when the cells are seen to contain caterpillars and before the caterpillars have changed into moths.* This would get rid of the moth pest and prevent it spreading and committing damage on a large scale in the lac areas. Beyond this somewhat drastic method of checking the pest it is impossible to go at present. A study of the lac predaceous pests is urgently needed. The insects themselves are doubtless preyed upon or parasitised.

(*c*) FUNGI.

Several species of parasitic fungi are known to prey upon scale insects of various kinds. No reports of any such infestation on lac have yet been made.

(*d*) NATURAL ATMOSPHERIC INFLUENCES.

Unseasonable heavy rain at the time of the swarming of the young larvæ often does very great and for the time irremediable damage to the lac insect. Frost and hail are also extremely harmful, the latter often battering in the cells, killing the insect, and ruining the incrustation.

(*e*) FOREST FIRES.

Small low leaf and grass fires running through a lac cultivation area would probably do little if any harm since the insect is protected by its scale or shell; the smoke alone would be unlikely to have a great

effect upon the lac since scale insects are notoriously hard to kill. Heavy jungle fires, however, are a most serious menace since a whole plantation might be entirely wiped out after the passage of such a one through it.

(*f*) Man.

As will be shown later, the ordinary methods of collection of the lac in vogue amongst the cultivators are extremely primitive whilst at the same time being very harmful.

No proper attention is paid to the future well-being of the tree while collecting the branches bearing the lac. They are often torn off the tree in a haphazard manner to the detriment of future supplies. Over-collection is also another result of a greed which wishes to obtain a maximum amount of profit from a particular crop without reference to future supplies or needs for propagation purposes.

CHAPTER VIII.

DISTRIBUTION.

The lac insect is widely distributed throughout the Indian continent and exists upon a variety of different trees. A peculiarity of this distribution, however, is that whereas it flourishes best on one or more particular species of tree in one locality in a different part of the continent it will be found to thrive on other species even though the trees upon which it does best in the former area may be present in the latter. This anomaly in the life history of the pest may be due to two causes :

(1) The host plant varies with the dryness of the atmosphere and the heat to which the insect is subject.

(2) There may be more than one species, sub-species, or race of the insect present in the country. This point, although of very considerable scientific interest and importance, has not, up to the present, received much attention and will not be pursued further in this paper.

These two conditions, which appear to affect the distribution and food plants of the lac scale, require to be borne in mind when experiments are made in introducing the insect into localities from which it is at present absent or in extending cultivation on a large scale. For instance, negative results would probably follow the attempted propa-

gation of the lac insect inhabiting dry hot localities such as Central India into the humid warm tracts of Eastern Bengal and Assam.

Before considering the methods of propagation and cultivation in force in India it will be advisable to consider here the distribution of the insect in the various presidencies and provinces in the Continent and the trees upon which it thrives best in these localities.

1. BOMBAY AND SIND.

In Bombay the chief lac industry appears to be confined to the Panch Mahals. It is obtained in small quantities from Dobad and from the forests of the neighbouring States of Ali Rajpur, Udepur, and Deogad Bariya. The chief lac-yielding trees are Ficus religiosa, Butea frondosa, Zizyphus jujuba, and Schleichera trijuga.

In Sind lac is found along the Indus and south of Hyderabad. It grows chiefly on Acacia arabica, but is also found on Prosopis spicigera, Zizyphus jujuba, Albizzia Lebbek, Tamarix gallica, and Ficus bengalensis.

2. CENTRAL INDIA AND RAJPUTANA.

In Rajputana the industry flourishes to a certain extent, whilst in Central India the insect is common throughout most of the area.

The chief host plants are Butea frondosa, Schleichera trijuga, and Zizyphus jujuba.

The two native States *par excellence* in Central India which cultivate lac are Rewah and Nagode. The principal tree in both is the Butea frondosa, the next being Schleichera trijuga The times of swarming of the larvæ and therefore of collecting the lac incrustation from the two trees vary, being later for the latter than for the former.

3. PUNJAB.

The lac insect is found throughout the Punjab. The chief trees used for the cultivation are the Ficus religiosa, Butea frondosa, and Zizyphus frondosa.

4. UNITED PROVINCES.

The lac insect flourishes in parts of the United Provinces and is to be found in small scattered quantities throughout the area. Attempts have been made to cultivate it in places on a large scale, but they do not appear to have met with great success.

The insect thrives best on Ficus religiosa, Schleichera trijuga, Butea frondosa, Zizyphus jujuba, Ficus bengalensis, Ficus glomerata, and Ficus infectoria. The best is that obtained from Schleichera trijuga and next Butea frondosa.

5. Central Provinces.

Lac cultivation is at its best in the Central Provinces. It is principally carried on in the reserved, unreserved, and private forests of the province.

The best trees for the cultivation are Schleichera trijuga and the Butea frondosa, but it is also grown on Zizyphus jujuba, Ficus religiosa, and Ficus glomerata.

6. Berar.

In Berar the chief cultivation of the insect appears to be in the Ellichpur, Basim, and Wun Divisions ; the chief trees being the Schleichera trijuga, Butea frondosa, Zizyphus jujuba, and Ficus religiosa.

7. Bengal.

In Bengal there may be said to be three distinct areas in which lac is cultivated : Rangpur in the east and the Santhal Parganas and Chota Nagpur in the west. In the east (from whence the insect extends away into Assam) lac is reared on Ficus infectoria, Cajanus indicus, and Ficus religiosa, the first two being the best.

The insect is grown throughout the Santhal Parganas District. Except in Pakour, where it thrives on the Zizyphus jujuba, the insect grows best on Butea frondosa. In Chota Nagpur it is found abundantly in the forest-clad areas. The best trees are the Schleichera trijuga and Butea frondosa, the lac on the Zizyphus jujuba and Ficus religiosa not being of so good a quality.

8. Assam.

Lac occurs in a natural state in many of the Assam forests and is reared more or less in most of the districts of the province ; Kamrup and the northern parts of the Khasia and the Garo Hills bordering on the Brahmaputra valley being the chief centres of the cultivation. It is cultivated on the ' arhar ' (Cajanus indicus) in the Garo Hills.

The insect thrives best on the Cajanus indicus and Ficus altissima. It can also be grown on Ficus cordifolia, Ficus comosa, Ficus elastica, Ficus religiosa, and Zizyphus jujuba.

9. MADRAS, COORG, AND MYSORE.

There is but a small production of lac in southern India. It thrives best on the Shorea Talura. In Mysore it is confined to the deciduous tracts of the Maidan.

10. BURMA.

The lac insect appears to be chiefly confined to Upper Burma, the principal exports of lac being derived from the Shan States. In Upper Burma (Katha and Yaw Divisions) it lives upon Dalbergia Oliveri, Shorea obtusa and Shorea siamensis, and also upon Dipterocarpus tuberculatus.

In the Shan States it thrives on Ficus religiosa, Ficus Rumphii, Dalbergia cultrata, and Butea frondosa.

There used, apparently, to be a considerable lac industry in Pegu in former days.

CHAPTER IX.

METHOD OF CULTIVATION AND PROPAGATION.

(*a*) GENERAL.

The cultivation and propagation of the lac insect are intimately connected with its life history. It has been shown that there are two broods of the insect in the year in most parts of the country with the exception of Madras, Mysore, and Burma, where there are three. Experience has shown, however, that in many parts of the country a crop can only be expected from the cold weather brood, that of the summer being usually only sufficient to re-stock the trees. This is generally attributed to climatic influences. The most general method of collection is to break off the twigs containing the lac incrustation about fifteen days before the young larvæ will swarm out. A certain number of these branches are lightly wrapped up in grass and placed aside for propagating purposes, being subsequently bound on to unaffected branches of the trees used for cultivating the insect. In the Central Provinces Palas fibre or rice straw is used for tying purposes, but any suitable material will serve equally well. Each twig should be from 9 inches to 1 foot in length and should be attached to the upper and middle branches of the tree. The grass tied round the twigs acts

as a means of communication from the lac to the branches and leaf petioles, thus saving many insects who would otherwise never live to reach the sappy branches. Owing to the crookedness and irregularity of the external surface of the lac incrustation and to the small size of the larvæ some such help is absolutely essential if a preponderance of the brood are to reach a position where they can obtain food and thus live. The young larvæ on swarming out of the lac cells spread by this means from the small lac incrusted twigs of the trees on to the unaffected ones. It is also of importance to tie the brood lac to the upper and middle branches of the tree, as by this arrangement many of the lower branches become covered with insects which are shaken or fall from above; if the lac is attached to the lower branches these insects will fall to the ground and be lost.

The native methods of cultivation and collection are extremely careless and slovenly, and result in injury to the crop and depreciation in the quality of the lac obtained. Formerly the lac-dye, the liquid with which the body of the female becomes filled at the time the eggs begin to form in the ovary, had a certain commercial importance. Consequently it was necessary to collect the lac at a period considerably *before* the larvæ swarmed. This is the origin of the native custom of collecting the product before the insects issue. The dye has now but little commercial value; still the custom remains, and it has become a matter of considerable controversy as to whether it would not now be better and cheaper to collect the lac after the larvæ have swarmed.

The cultivation and propagation of the insect on scientific lines has been receiving considerable attention from Mr. A. Lowrie, Deputy Conservator of Forests, in the Raipur Division, and the following note which was forwarded to me by Mr. G. S. Hart, Conservator of Forests, Western Circle, epitomises the best methods at present in force in that locality:

"The mass of the lac is collected, almost invariably, before swarming takes place; but in order to explain the reasons for this it will be necessary to give a brief outline of the method of cultivation adopted and to note the species on which this cultivation is principally carried out. The species are 'Kusum' (*Schleichera trijuga*), 'Palas' (*Butea frondosa*), 'Khair' (*Acacia Catechu*), 'dhobin' (*Dalbergia paniculata*) and 'Ber' (*Z zyphus jujuba*), while lac has also been noticed on 'Ficus infectoria,' where this tree is epithitic on 'Kusum' under lac cultivation. Of these species the lac produced on the Schleichera trijuga

is by far the best, the crop being greater in quantity and better in quality than that produced on any other kind of tree. Probably this is partly due to the fact that by March the ' Kusum ' is in full leaf and so affords shade and shelter to the young insects at the time they are incrusting themselves. The insects swarm in February and in the last week of June or the beginning of July, the lac being collected during June and from about the 15th December to the 15th January, before swarming takes place. About 10 per cent. of the crop is kept as seed-lac, either special trees being reserved or a portion of the crop left on each tree, and when swarming time approaches the twigs covered with lac are loosely wrapped in rice straw and are tied on with more straw to branches of the ' Kusum ' about 12 to 15 inches in girth, so that as the insects swarm they work up on to the smaller leaf-bearing branches and then proceed to produce a first crop of lac. The lac used for propagation is not wasted, however, for as soon as the insects have swarmed and got fixed, the seed lac, from which they have swarmed, is collected. In this manner the whole of the crop is collected, about 90 per cent. before swarming and 10 per cent. after swarming, while future propagation is arranged for by placing the seed-lac in a favourable position instead of leaving the young insects to shift for themselves as they swarm from the ends of the small and already infected branches, when it is probable that a very large percentage are destroyed at once.''

This provision of bridges to enable the twig-swarming larvæ to reach unincrusted branches is of the utmost importance. Nature's method to ensure the continuance of the species has been the production of a very large number of offspring owing to the certainty of large numbers perishing in the effort to reach suitable feeding places. Man, by assisting this latter operation in every possible manner, can turn to his own advantage this great profusion of offspring.

At the time of the escape of the larvæ the female insect is dead and is represented by little more than a shrivelled skin.

The lac-incrusted twigs, called brood-lac, from which it is required to propagate the insect should not be cut off the trees until just before the period of swarming. Should they be cut too soon the sap dries up and the female insect in which the eggs are maturing will be killed.

(*b*) IN AREAS UNDER THE FOREST DEPARTMENT.

The following information on the subject of the cultivation of lac

in Government forests has been received as a result of questions addressed to the Conservators of Forests in India :—

1. Hazara, North-West Frontier Province.

No lac is at present produced in the forests of this province.

2. Bombay and Sind.

No lac is exploited in the Southern Circle of the Bombay Presidency and the Conservator states that he is not aware that it exists in the circle.

In the Northern Circle the Conservator states that lac is not a commercial product of the forests, and although it may be occasionally seen on various kinds of trees no steps towards its cultivation appear advisable.

In the Central Circle of the Presidency lac is present in the West Khandesh, Nasik and Satara Divisions.

In the West Khandesh the area of forest lands yielding lac cannot be stated, as the produce is not collected departmentally but on a small scale only by Bhils. Zizyphus jujuba, Ficus religiosa and Schleichera trijuga are the chief lac-bearing trees.

In the Nasik Division the area of forest lands from which the product is obtainable cannot be given. In three ranges only, *viz.*, Chandvad, Kalwan, and Dindori, is it collected, and this collection is undertaken entirely by the local inhabitants who cut off the branches and scrape off the lac. In Kalwan after collection the lac is boiled and made into cakes. The chief trees are the Zizyphus jujuba, Ficus religiosa, Ougeinia dalbergioides, and *Veltur* (?).

In the Satara Division also the area cannot be given. The collection is small and departmental collection said to be financially impossible. The trees are Ficus cordifolia and Xylia dolabriformis.

The Conservator states that no steps are being taken to increase the area under lac anywhere and no royalty is obtained from it in the circle.

3. Punjab.

Lac is not cultivated in the Punjab forests, and the Forest Department derives no revenue from the product. The Conservator states that no steps are taken by Government to increase the outturn of lac, and as there is no lac in the forests under the Department, no attention has been paid by the latter to the matter. The trees on which the insect lives are Zizyphus jujuba, Acacia arabica, Butea frondosa, and to a small extent Ficus religiosa and other figs.

4. United Provinces.

Until recently no lac cultivation was undertaken in the forests of the Western Circle. Experiments have now, however, been commenced in the Siwalik Division, in the neighbouring district lands of which lac cultivation is undertaken. These experiments are being carried out in the Western Range and are to be introduced into the Eastern Range also. Seed-lac is being propagated on a certain number of Butea frondosa trees.

No royalty has yet been realized by Government on this product.

The trees locally used by villagers are Butea frondosa, Ficus religiosa, Albizzia Lebbek, and Acacia Catechu.

Mr. Hobart-Hampden, Director of the Imperial Forest School, and formerly in charge of the School Circle to which the Saharanpur Division belonged, forwarded the following note on the subject :—

" The villagers below the forests in the eastern part of the Saharanpur Division cultivate lac on Butea frondosa in their fields and I proposed this in the Pathri forest (13,000 acres of nearly solid Butea). If successful it would be, in my opinion, excellent to try it on Butea, Khair, Kusum, and other trees in the parts of the Saharanpur hills which are inaccessible for timber work, but which must be fire-protected, as protection to the canals down country, among other things. The Range Officer of Barkela Range has tried it on a tree near his head-quarters and found it spread well. "

In the Eastern Circle, with the exception of Bundelkhand, no lac is artificially raised in the forests. It occurs to some extent in both the Bahraich and Kumaon Divisions although the area over which it exists is unknown.

In the Bahraich Division an annual contract is sold for about R50 per annum in the Motipur Range, the contractor making his own arrangements for the collection. It exists here on Butea frondosa and Ficus religiosa.

In the Kumaun Division the Conservator states that lac occurs naturally here and there in the miscellaneous forests of the Bhaber, chiefly on Butea frondosa trees. The right to collect it is sold to contractors together with numerous other minor products for a lump sum.

In the Bundelkhand Division the area of forest land from which lac is collected is 38,025 acres. It is reserved forest situated in the extreme south and south-east of the Lalitpur Range in the Parganas of

Melironi and Maraura. No lac is collected from the protected or unclassed forests. The trees in the order esteemed for the purpose are Zizyphus xylopyra, Acacia Catechu, Butea frondosa, Zizyphus jujuba, and Ficus infectoria.

The Divisional Officer of the Bundelkhand Division forwarded the following note on the subject of propagation and cultivation of the lac :—

"The collection is done by the local inhabitants, an aboriginal tribe known as Sahirujas, who dispose of the lac to the lac cultivator who pays the Government royalty; the area in which lac is collected is put up to auction. The collectors cultivate the lac by removing insect-bearing twigs about a foot long and tying them on to other young trees in the forests; the trees selected for the purpose are those growing on dry, rocky soil with preferably no grass under them; the vicinity of streams is considered undesirable as the insects are said to be injuriously affected by damp and frost; forest fires are said to reduce very considerably the yield of lac on an area.

"About three-fourths of the lac collected contains the insects in it, the remaining one-fourth consisting of lac collected after the insects have swarmed out. The lac collected after the insects have swarmed out is much lighter in weight than that collected before; but the quality of the former is said to be the better. The occurrence of rain tends to improve the outturn of lac if the insects are in it; but considerably reduces the yield if they have swarmed out. There are two crops of lac in the year, namely, the spring crop (April-May) and the autumn one (October-November); the autumn crop is the better of the two. The cultivation of lac is on the decline as more remunerative labour is easily procurable in the form of cultivation of crops, cutting of wood and bamboos, etc. The amount of stick-lac collected in this Division is said by the contractor to be about 25 maunds; it sells in the Saugor market for R40 per maund of 50 seers. The value of lac in Government royalty obtained is R250 per year."

5. Central Provinces.

A very considerable amount of lac cultivation is undertaken in the reserved forests of the Southern Circle. The following is an interesting note by the Conservator on the subject :—

"I should mention in the first place that there are no protected or unclassed forests, and consequently that all the figures quoted refer to reserved forests only.

"The area of forest lands from which lac is obtained and the distribution of that area over the various Divisions is shown in the following table :—

Name of Division.	Area in acres from which lac is obtained.
Balaghat	2,000
Raipur	340
Bhandara	1,400
Bilaspur	1,100
South Chanda	135,000
North Chanda	370,000
TOTAL .	509,840

"The very large areas given in the North and South Chanda Divisions merely represent the fact that the lac occurs on scattered trees throughout the area. In the other Divisions the figures represent the approximate area that actually bears lac."

"The trees used for the propagation of lac are Butea frondosa, Schleichera trijuga, Zizyphus jujuba, Zizyphus xylopyra, Acacia Catechu, and Dalbergia paniculata. Lac occurs on other species also, but the above are the only trees reported to be used for propagation."

Mr. Lowrie's letter above quoted details the methods of cultivation adopted in the Raipur Division where the work is under departmental supervision. The method of cultivation adopted by the local inhabitants is to break or cut the lac-bearing twigs before swarming takes place, and then when the lac has been dried in the sun to rub off the incrustation. To increase the yearly amount of lac obtainable from the forests where the right to collect lac is sold to contractors the latter are bound not to remove more than from 60 per cent. to 75 per cent. of each crop, leaving the remainder for the purpose of seed, and also to infect a certain number of fresh trees in each year. They are encouraged to

continue this work by the grant of leases for periods of from three to five years on a gradually rising yearly rental.

The value of the lac in Government royalty obtained from the Divisions in the Circle is as follows :—

Division.	YEARS		
	1903 04.	1904-05.	1905-06.
	R	R	R
Balaghat	1,000	1,000	5,017
Raipur	5,300	5,300	6,000
Bhandara	Five hundred and twenty-five rupees a year average.		
Bilaspur	One thousand six hundred and eighty rupees a year average.		
South Chanda	105	137	211
North Chanda	...	125	3,500*

*Lac collected departmentally and sold.

The annual value of lac collected from Government forests and from Zemindari and Malguzari forests may be put at R46,000 and R8,40,000, respectively, though the latter figure is nothing more than a rough estimate.

The lac industry in this circle would appear to have a great future before it.

The Annual Report of this circle for 1905-06 has the following remarks on lac :—

" The introduction and extension of lac was continued. It is reported that the experiments were successful in the Gaikhuri, Lachni, Partabgurh, and Pauni Ranges in Bhandara, but that they failed in the Bawanthari Range of the same Division and in the Dhaba Range of North Chanda. In this latter Division it is probable that experiments, which have now been started in the Kusum (*Schleichera trijuga*) areas of the Moharli Range, will be more successful. In Balaghat the work of infecting fresh lac nurseries was continued through the agency of the lac

contractor, while attempts are being made to interest forest and other villagers in this cultivation. These attempts, which provide for adequate payment of the villagers by the contractor, promise to be successful.

The most interesting experiments of the year were those undertaken in Raipur with the object of developing the lac and other minor produce industries. The areas selected were parts of the Laon and Sirpur Ranges, and a special establishment under an Extra-Assistant Conservator of Forests was sanctioned for the control of the work. It was known that Malguzars were making considerable sums out of the cultivation of lac on Kusum (*Schleichera trijuga*), and with the object of ascertaining the possibility of the forests an enumeration of these trees was started which resulted in 20,000 trees being found. Seventeen forest villages were started to provide labour, and the villagers were induced to take up the cultivation of 1,076 Kusum trees on the understanding that they would receive $\frac{3}{4}$ths of the crop. It was anticipated that the hot weather crop from these trees would provide enough seed-lac to increase the number of trees cultivated to some 4,000 to 5,000 ; but unfortunately bad weather prevailed through the swarming season and was followed by unusually intense heat in April, May, and June, so that the greater part of the crop failed. About 1,000 trees have, however, been infected for the winter crop, and it is hoped that the result will be satisfactory. It is estimated that there are at least 150,000 Kusum trees in the Raipur forests and that each tree under cultivation should give an average annual profit to Government of not less than R2. There is therefore an enormous industry awaiting development, which development depends entirely on the possibility of obtaining labour. It is unlikely that we shall be able to work up to the full possibility, but it is anticipated confidently that with one or two successful seasons we shall have no difficulty in greatly increasing the labour supply as the people get to know that they will experience fair treatment when working in the Government forests. Apart from the Raipur District there are great opportunities for the extension of lac cultivation in Bilaspur, Balaghat, North Chanda, and Bhandara, so that it may be said that the future revenue of the circle depends to no little extent on the successful extension of this industry.

Lac is also cultivated to a considerable extent in the Northern Circle, the following notes being compiled from an interesting report received from the Conservator. The trees in use are the Schleichera trijuga, Zizyphus xylopyra, Butea frondosa, Zizyphus nummularia, Ficus infectoria, Zizyphus jujuba, Ficus religiosa, and Ougeinia dalbergioides.

There are two crops of lac in the year. One is called "Katki" (November) and the other the Baisakh (April-May) crop. The insects swarm in December.

In the Narsinghpur Division no lac is collected departmentally from the unclassed forests. It is collected more or less from the entire area of reserves, 159,392 acres, the greater quantity being found in 47,480 acres of the Richai Range. No lac is collected departmentally. It is leased to contractors who employ coolies to cut the twigs on which lac is found, the coolies receiving R1 per 8 seers (*Kurha*). Lac is being propagated by lessees more or less over 87,993 acres and over 851 acres in the Bandha block.

In the Hoshangabad Division lac is found in scattered plots over the entire area of 161,025 acres of reserves, none being collected in the unclassed forests. No departmental collection is undertaken. The lac trees are leased to contractors who employ labourers to cut the lac-bearing twigs before the larvæ swarm. The twigs are collected in bundles and dried for fourteen days, then beaten with wooden mallets to separate off the lac, or the lac-bearing twigs are sold in bundles. The lessees working in reserve forests sign an agreement to leave a certain amount of lac on each tree for propagation. In certain cases they are obliged to bind brood-lac on a specified number of trees. Experimental steps are being made departmentally in the Hoshangabad Range to rear lac on the Butea frondosa.

In the Chindwara Division no lac is obtained from the unclassed forests. In the reserves lac trees are scattered over approximately 22,000 acres. No departmental collection is undertaken. Leases for lac collection are given out for one to three years, the contractors engaging their own coolies. The lessees are bound to leave a certain amount of lac on the trees for propagation. The revenue per annum has increased in the last three years from R200 to R700.

In the Damoh Division lac is collected by contractors over 400 acres of unclassed forests and over 76,781 acres of reserves, chiefly from Zizyphus xylopyra. Both classes of forests are leased out to contractors who employ the local inhabitants, chiefly Bharias, Kawats, and Gonds. The twigs are cut before the larvæ swarm and collected at centres in the forest called '*parwas*.' The lac is removed from the twigs by the hand and taken thence to depôts where it is weighed and made over to the lessees. The rate for collecting varies from 10 to 16 seers the rupee. According to the terms of his contract the lessee is bound to leave at least half the lac on every tree for propagation purposes and he may not cut

twigs over 6 inches in girth. He is also held responsible for propagating new areas.

In the Seoni Division no lac is collected from the unclassed forests. It is found scattered here and there in small quantities over 285,086 acres in the reserves. It is leased out to contractors on one to three years' leases. The lessees issue permits to Gonds, graziers, and local villagers to collect the lac for them, paying them at the rate of 5 to 6 seers for the rupee. In their agreements the lessees are bound to collect the lac as far as possible after the swarming of the larvæ, to leave two-thirds of the lac on the trees, and to propagate lac on fresh areas.

In the Saugor Division lac is scattered in small quantities over 220,216 acres of reserves, none being collected from the unclassed forests. It is not collected departmentally, but leased to contractors who pay the local inhabitants, chiefly Gonds and Sours, to collect it. They cut the twigs in the sowing season, *i.e.*, beginning of June and November and beginning of December. The lac is scraped off the twigs with blunt knives, dried in the sun, and then sold. For the last three years a small sum of R50 has been provided in this Division for the propagation of lac, but little has been done owing to the scarcity of brood-lac. In the Rangir forests (area 10,152 acres) a good deal has been propagated by contractors and also departmentally.

In the unclassed forests of the Betul Division no lac is collected. In the reserves it is collected by contractors from patches of 5 to 20 acres in extent scattered over the area. It is collected for the contractors by the *Kurkus*, a jungle tribe. The Gonds will not touch the lac owing to caste prejudices. This is said to check the industry as the lac is only propagated in the neighbourhood of *Kurku* villages. The lessees are bound to extend the cultivation of lac, wherever suitable trees are available, under departmental supervision, and are also obliged to leave two-thirds of the lac on the trees. Severe frost affected the lac in 1905.

In the Jubbulpur Division lac is only collected over 2,605 acres of reserves, none being taken from the unclassed forests by the Department. It is worked departmentally on a small scale in block 39 as an object-lesson to lessees to induce more to engage in the industry. The lac is collected for the lessees by the local inhabitants before the larvæ issue, every effort being made to obtain good lessees who are in a position to undertake the work on a large scale.

In the Mandla Range lac is collected over an area of 918,400 acres. A small area of 100 acres in the Shahpura Range is worked departmentally

for the purpose of distributing brood-lac to lessees. The rest of the area is leased to lessees who arrange for the collection of the lac with the local inhabitants. By the terms of the lease the lessees are bound to propagate lac on a specified number of trees. The number of trees varies according to the area leased. The lessee is bound to leave one-third of the lac on each tree for purposes of propagation.

The income realized from lac in the Northern Circle is as follows :—

Division.	DURING CURRENT YEAR OR ANNUALLY.		REMARKS.
	Reserves.	Unclassed forests.	
	R		
Narsinghpur	691	..	
Hoshangabad	837	..	
Chhindwara	695	..	
Damoh	16,400	..	From reserves and unclassed forests together.
Seoni	1,404	..	For year ending June 30th, 1907.
Saugor	1,738	..	
Betul	900	..	
Jubbulpur	586	..	Average for last three years.
Mandla	1,223	..	
Total for Circle .	24,474	..	

6. Berar.

In the Berar Circle lac is only found to any appreciable extent in the Ellichpur and Wun Divisions.

In the Ellichpur Division lac is found throughout the Melghat forests, the area being, reserves 843 square miles and c. III class forests 656 square miles. It is most plentiful in the eastern half of the Bairagarh Reserve.

The following are the chief trees upon which the insect lives in their order of importance :—

Zizyphus xylopyra, Schleichera trijuga, Butea frondosa, Zizyphus vulgaris, Ougeinia dalbergioides, Ficus religiosa, Ficus bengalensis.

The lac is collected by the aboriginals of the forest villages in the reserves and brought to depôts. In the c. III class forest the right to collect lac is annually leased. No steps are being taken to increase the yearly amount of lac ; when collecting a sufficient quantity of brood-lac is left on the trees for propagation purposes.

The quantity and value of lac collected is as follows :—

Forest areas.	YEAR.					
	1903-04. FOREST YEAR.		1904-05. FOREST YEAR.		JULY 1905 TO FEBRUARY 1906.	
	Amount.	Value.	Amount.	Value.	Amount.	Value.
	Seers.	R	Seers.	R	Seers.	R
Reserves	731	109	2,276	1,896	3,457	3,109
					Forest year 1905-06.	
C. III class forests . .	..	50	..	992	..	842

Matters are not so satisfactory in the Wun Division. It is said that since the famine of 1896-97 the rainfall in the Division has been so scanty and fitful that the lac insect has ceased to thrive, the long breaks in the rains being particularly detrimental to it. Lac only exists in the State forests of class A, chiefly in Kinwat. Here lac-bearing trees exist scattered over the area of 179 square miles, being chiefly abundant in the Mohadi block, area 6,788 acres, where the abundance is attributed to the preponderance of Ougeinia dalbergioides which is the chief lac-bearing tree. Next in order comes Butea frondosa. It is said to be found only rarely on Schleichera trijuga, Zizyphus vulgaris, and Terminalia tomentosa.

An attempt was made in the rains of 1905 to propagate the insect on Ficus religiosa, but no success resulted owing to the unfavourable nature of the weather experienced.

The local inhabitants are authorized to collect the lac for Government and are paid at the rate of 2 annas per seer of 2 lbs. of collected lac. This is then sold at 8 annas per seer. The royalty collected on the lac averages about R20 per annum. The trees are not lopped in the collection, but the branches merely bent over and lac broken off the twigs which are then released—a most deplorable method of procedure.

No special steps are being taken to increase the yearly amount of lac obtainable from the forests of the Division. Attention to the cultivation of Ougeinia dalbergioides and to improved methods of collection would doubtless result in better returns from this Division.

7. Bengal.

Chota Nagpur and the Santhal Parganas are the chief lac-producing areas in Bengal. The Conservator writes that it is useless attempting to estimate areas of reserved and protected forests in which lac is grown. Trees of suitable kinds in accessible parts are used when the lac cultivators outside the forest have not sufficient trees outside the reserved and protected areas.

The lac-growing divisions are the Santhal Parganas, and Palamau, Hazaribagh, and Singbhum in Chota Nagpur.

The trees used are Schleichera trijuga, Butea frondosa, Ficus religiosa, Zizyphus jujuba, Ficus Cunia, Butea scandens and Spatholobus Roxburghii. The Butea frondosa, on account of its abundance, is most commonly used, whilst the Schleichera trijuga is the only other tree employed to any extent.

No steps are being taken in Bengal to improve or extend lac cultivation. The right to grow lac on individual trees or in areas is leased when lessees come forward. Past departmental experiments have been unsatisfactory. This is so! But the reason in several notable instances, such as the introduction of brood-lac from unsuitable localities into Darjiling and the fiasco attending the Palamau experiments made about 1894-96, has been due to the fact that the method of culture of the insect was entirely misunderstood and no efforts were made to study its life history. The attempts made, as in so many other cases in India, were foredoomed to failure.

The revenue from leases of trees and areas and from royalty on lac has been—1902-03, R91; 1903-04, R226; 1904-05, R674.

The Conservator states that generally in Bengal, with the exception of the Santhal Parganas, where most of the protected forests are

only forests in name, the people who wish to grow lac can find ample scope outside the forests, where the danger of theft is less.

In Palamau and Hazaribagh lac is only collected by the Department in the reserved forests, which total an area of 245 square miles, the protected forests being under the civil authorities. In this area the right to cultivate is only leased in Betla and Kechki, area 10 square miles, and in a few of the rest-house compounds and on individual trees in the Oriya block , area 1 square mile. No departmental work is undertaken. The Divisional Officer of Palamau states that the villagers do not care to cultivate in the reserved or protected forests because (1) the trees are more scattered than outside ; (2) theft of lac by the wilder tribes of the district is common and the trees outside are more easily guarded ; (3) that outside the people can lop as they like ; and (4) the trees grow bigger and more branchy outside.

8. Assam.

Lac is only obtained from the unclassed State forests of Kamrup, Nowgong, Khasi and Jaintia hills, and Garo hills Divisions in Assam. The area in Kamrup and in the Khasi and Jaintia hills is unknown, but in the Garo hills and Nowgong the area under lac is 192,000 and 271,464 acres, respectively.

The trees used are Cajanus indicus, Ficus Rumphii, Pithicolobium bigeminum, 'Gouhaitola,' 'Kaorthanga,' Thespesia Carr, 'Gangmang,' 'Suktapatea,' Echinocarpus assamica, Jamiferus macropoda, 'Chinamlongdak, Charœtengia sp., Flemingia congesta, Ficus altissima, Ficus alternarine, Grewia lævigata, Ficus cordifolia. The lac raised on Cajanus indicus (*arhar*) can be put on to other lac-raising trees.

The lac is collected by the local inhabitants by cutting off the twigs and branches and taking them to the bazars for sale. No lac is collected departmentally, and at present no steps are being taken to increase the amount of lac obtainable from either the reserves or unclassed forests.

The revenue realized during 1905-06 was R32,507, as follows :— Kamrup, R3,710 ; Nowgong, R8,100 ; import duty on lac from Khasi hills, R8,665 ; from Garo hills, R12,032.

It would seem a pity that the question of lac cultivation is not taken up more seriously in Assam. It has been said that a crop can be obtained from Cajanus indicus in three years with proper cultivation. It would appear advisable for the Forest Department to take up the question with the object of showing what can be done by scientific management. It may also be suggested that the planting community

might with advantage turn their attention to this valuable commodity for which the export figures evidence such a large demand.

9. Madras and Coorg.

No lac is collected in the Southern and Central Circles of the Madras Presidency. In the latter the occurrence of the insect is said to be so rare that the quantity of lac that could be gathered would not repay the cost of collection.

The only Division in the Northern Circle in which the Distr ct Forest Officer was able to furnish any information on the subject of lac was n Anantpur. No lac has ever been collected departmentally or by private enterprise in this district. The cultivation is undertaken in the adjoining territory of Mysore. An application was recently received from a contractor asking for permission to extract lac from Shorea Talura in the Anantpur forests. It is also found on Schleichera trijuga in the Jeypore Estate in the Vizagapatam District. The Conservator wrote: "There is but little of it in any of the reserves of this district, and though possibly a small trade could be opened up, the District Forest Officer thinks it inadvisable, at any rate at present, in any way to denude further the bare hills."

Evidently the importance and value of lac cultivation is not understood in the Presidency.

10. Burma.

The lac insect apparently exists to a certain extent in Burma, being most abundant in Upper Burma, becoming rarer as one goes south to Tharrawaddy and Rangoon, and disappearing entirely in Tenasserim in which circle the Conservator reports it is entirely absent.

In an interesting note Mr. J. H. Lace, at the time Conservator, Pegu Circle, wrote as follows :—

" The Divisional Officers in this circle give very little exact information regarding the distribution and collection of lac, and show that little is known about the product, which is probably due to its scarcity. The forests of Zigon, Rangoon, Pegu, and Bassein Divisions are stated to contain no lac and those of the Tharrawaddy Division very little. No reliable information of the areas from which lac is obtained in the Thayetmyo, Prome, and Henzada-Thongwa Divisions is forthcoming. It is stated that a very small quantity of lac is found in Arakan, but that occasionally fairly large consignments are imported from the unadministered tracts of Northern Arakan.

" The species of trees on which the lac insect is found are said to be very numerous ; amongst them the most common are Schleichera trijuga,

Shorea obtusa, Pentacme suavis, Butea frondosa, Dalbergia cultrata, Dalbergia ovata, Xylia dolabriformis, Cassia siamea Zizyphus jujuba, Dipterocarpus tuberculatus, Albizzia Lebbek, Albizzia lebbekoides, Tamarindus indica, Garuga pinnata, Stereospermum fimbriatum, Croton oblongifolius, Streblus asper, Glochidion sp., and, amongst introduced species, Pithecolobium Saman and Anona squamosa. No mention is made in divisional reports of Terminalia tomentosa on which common species I think I have seen traces of the lac insect in the Thayetmyo District.

" Lac is not collected by the department in this circle, but leases to collect it are issued in the Thayetmyo and Prome Divisions and the right to collect is sold by auction in the Henzada-Thongwa Division. The general method of collection is by breaking off the twigs on which the lac is found and sometimes the lac is picked off the trees.

" No steps have been taken to increase the amount of lac obtainable from the forests of this circle and the insects do not appear to be cultivated by the Burmans who leave their cultivation to chance."

The revenue for the last three years is as follows :—

Division.	Years.		
	1903-04.	1904-05.	1905-06.
	R.	R.	R
	Reserved forests.		
Thayetmyo	60	40	60
Henzada-Thongwa	1,245	..	..
	Unclassed Forests.		
Thayetmyo	10	15	18
Prome	68	76	25

In the Henzada-Thongwa Division the sale of the monopoly to collect lac was discontinued in 1905 owing to a report that the supply was failing. If, as is apparently the case, no efforts are made to ensure the retention of a certain amount of seed-lac upon the trees for the

propagation of the insect it is readily understandable that in time the supply must fail, since the stick-lac is collected before the young larvæ issue.

In the Northern Circle of Upper Burma the lac insect is reported to only occur in the Upper Chindwin Division. During 1904-05, 253 viss or 800 lbs. were collected in this Division, but there is no record to show whether it came from the reserved or unclassed State forests. The insect is believed to exist in the Chindwin hills. The Officer in charge of the Mansi Sub-Division of the Chindwin reported that there are about 53 square miles of lac-producing area in the Upper Chindwin in the Chaunggyibya and Sanda Reserves and on the Chaunggyibyameza watershed. The trees on which the insect lives are Pentacme siamensis and Dalbergia sp. The former is the tree most favoured in Burma where the insect is said to never propagate on Butea frondosa as in India. The lac is not collected departmentally. Licensed traders engage villagers at 4 annas per viss for stick-lac and 8 annas per cleared lac delivered at Pinbon, 10 miles from the lac-yielding forests.

Burmans adopt a very wasteful way of collecting by felling the trees if of small girth. This, however, has been stopped and the lopping of the smaller branches only is allowed. A skilled Collector in a good year could gather eight to nine viss in a day and half this amount when scarce. The time of collection of stick-lac is in October before the young broods swarm. The produce is then packed in sacks or baskets with salt or wood-ash to prevent the young working their way out. No steps are taken to propagate the species, but experiments will be made next season.

The following extract from the forest settlement proceedings of the Chaunggyibya Reserve is of very considerable and curious interest. There was here every chance of starting, through a mere accident, a very thriving industry, had it not been for the wasteful method of collection by felling the trees employed by the Burmans. The incident, however, forms an object-lesson as to the great possibilities of lac cultivation in this neighbourhood. The extract is as follows:—

"The lac insect first made its appearance in this locality in the year 1894, during, it is said, the prevalence of a strong wind from the south; and it is supposed that a swarm of the insects was carried by it from the spurs of Maingthon, which is some 50 miles nearly due south. This account is at least plausible and is probably correct. The insect has its home in the neighbourhood of Shimpa Maukwin and Maulin in the Wuntho Township. If a swarm were blown nearly due north

from that locality, the Seisepa Range (elevation 3,700 feet) contains the first hills which would be likely, from this considerable height, to intercept its course. A smaller number lodged on the lower and nearer hill of Petongtung (probably Petaungting, a Kachin survival). The arrival of the insect was naturally regarded as a valuable windfall by the Anankta people who lost no time in turning it to account and sold, in Scatha chiefly, some 1,000 viss of lac. This was quickly put a stop to and since that time the insect has remained unmolested. It is stated never to have existed in large numbers on Petongtung, whence it has now entirely disappeared, while it still survives on the higher and more northerly ridge of Seikpa. The lac insect under favourable conditions increases very rapidly, two generations being hatched in each year in July and December. To obtain the greatest quantity of the liquid which produces the dye as well as the stick-lac the twigs which carry it must be gathered before the young are allowed to hatch and any increase is thus effectually checked.

" The lac insect in the Chaunggyibya has, however, enjoyed complete immunity from molestation for several years, except perhaps occasional forest fires ; and if within a reasonable time it has not shown a very great increase, it may, I think, be safely inferred that the particular kinds of trees from the sap of which it draws its nourishment do not exist in sufficient numbers to favour any considerable increase of the insect."

In the Southern Circle of Upper Burma practically no lac is obtained from the Pyinmana and Pakokku and Ruby Mines Divisions. In Pyinmana the insect is said not to exist in commercial quantities and no information is available. In Pakokku the lac insect only occurs in the Chindwin hills (unclassed forests) and the extent of lac-producing country is unknown. Duty on lac is not collected till it reaches the hands of Burmese traders outside the hills. The collection was not enforced till 1904-05 when R349-2-9 were obtained—

The important report of the Superintendent of the Chindwin hills will be found under 'District Lands' below.

In the Ruby Mines very little lac is obtained, and that only from the unclassed forests from small bushes widely scattered over an area of six square miles. No artificial production is undertaken. The trees are chiefly Zizyphus jujuba, species of Ficus, Castanopsis, and Bauhinia. No steps are being taken to increase the production. The value realized was R38 in 1904-05 and R30 in 1905-06.

In the Mandalay Division lac is mostly obtained from the Northern Shan States, especially the State of North and South Theinni, but a little is also obtained in the Maymyo Sub-Division. The lac trees are scattered and the area over which it occurs cannot be estimated. It is most commonly found on species of Ficus, Schleichera trijuga, Albizzia Lebbek, Zizyphus jujuba and Tamarindus indica.

The collection of lac is said to take place from May to November, but the quality is poor till August. The larger branches of the trees are cut off and sent down country in this state. When the areas of collection are distant from the railway the lac is first stripped off the branches. All the lac comes from the unclassed forests and no steps are taken to increase the quantity. Duty was collected for the first time during 1905-06 (on lac exported by rail only) when a sum of R6,326 was realised.

The methods of collection and export for the Southern Shan States are the same as those for the Northern.

The list of trees used is, however, different : Shorea obtusa, Schleichera trijuga, Dalbergia latifolia, Ficus nervosa, Ficus obtusifolia, Ficus religiosa, Butea frondosa, Pentacme siamensis, and Mangifera indica.

No duty was collected on lac in these States, nor are any steps taken departmentally to increase the production or collect departmentally.

In the Minbu Division lac is obtained from an area of about 9 square miles (two reserves and seven unclassed forests). No artificial cultivation is, however, undertaken, and no propagation. The branches bearing the lac are lopped off the trees and sold in that state. No steps are being taken to increase the amount of lac. R100 even obtained from the collection of lac during 1906-07.

Summary.

It will have become abundantly evident from a perusal of the above reports that, with the exception of the Central Provinces, the Department has not realized the immense value of lac as a minor forest product. It may be held that lac cultivation is not the work of the Forest Officer, and when the cultivation has been taken up in a systematic manner throughout the country it may well be that the Forest Department will be in a position to make it over to the villager in the district lands outside reserves, to the Native State, and to the private Zemindar. At present, however, the position has to be faced that the cultivation of the product on scientific lines is not understood. But little advance has been made in the production of the substance since the days of Akbar

and the daily increasing demand for the product, of which India is the chief producer, would seem to necessitate considerably more attention being paid to its proper collection than has been the case in the past. To this end, since it is peculiarly a product of tree cultivation, it would seem desirable that the Forest Department should turn its attention to working out the best methods by which a largely increased and sustained yield can be obtained and to cultivating object-lesson crops all over the country with a view to gradually weaning the native cultivator from his at present quite inadequate methods of supplying the existing demand. As matters are now shaping there appears to be but small reason to doubt that money expended in this work will yield very large returns.

(c) IN DISTRICT LANDS.

1. Bombay.

Very little lac cultivation seems to take place in the Bombay districts. Bombay appears to import most of its lac from the United Provinces and Oudh. Lac is produced in small quantities in Dobad in the Panch Mahals.

2. Sind.

Mr. G. M. Ryan, I.F.S., wrote the following note on lac in Sind in 1896 which is reproduced here. When it is remembered that exports of lac from Karachi have reached the figure of R5,49,335 (in 1904-05) the question of the extension of the cultivation would seem to be worthy of consideration. Mr. Ryan wrote :—

Trees on which lac is found.—"Babul (Acacia arabica), Kandi (Prosopis spicigera), ber (Zizyphus jujuba), sirus (Albizzia Lebbek), banyan (Ficus bengalensis), tamarisk (Tamarix gallica) are the trees on which lac may be seen in the province. Most of it, however, is collected from the babul which grows gregariously along the Indus, forming dense forests. Kandi in places is also gregarious, but the insect does not usually affect this tree under such conditions. On Kandi it is found about 12 to 14 miles south of Hyderabad along the left bank of the Fuleli, chiefly where the two species Kandi and babul are mixed, and occasionally in the Khipra Taluka in Thar and Parkar. The insect does not appear to be known on this tree at all north of Hyderabad. On ber, sirus, and banyan, it is seen mostly along road-sides and banks and canal banks. There is one banyan just below the Hyderabad Gymkhana on the road-side which bears a splendid crop every cold weather."

Crops of lac.—"There are two seasons for gathering lac, one being in the cold weather and the other in the hot. The cold weather crop is

commenced to be gathered when the northerly winds set in in November, and the gathering continues till January or February. The hot weather harvesting of the crop begins with the setting in of the south-westerly breezes in April and lasts till June. The latter, though not so plentiful, is a better crop in value than the former, realizing as much as R5 per maund more. The crop on the banyan (Ficus bengalensis), however, is an exception. Its cold weather crop is both more plentiful and valuable than the summer crop. In order to secure a supply of lac for the following year, some of the incrustation, containing of course the live insects not yet fully developed, is left on the branches of the trees at the time of gathering. The period when the insect is likely to be ready for swarming out of the incrustation is well known to the gatherers, and about a month or so before this most of the produce is collected, while the remainder is left behind on the branches to form a nucleus for the succeeding crop. Those insects left on the trees swarm out and cover the tender branches in January and July for the two crops respectively."

Cultivation of lac.—"It is during these months that it is possible to extend the area under lac by artificial means. Small branches, covered with the incrustation, are cut off and transferred to tender and succulent branches of other trees, in perhaps a totally different locality where lac does not exist. In making the transfer care has to be taken to place the cut-off branches, bearing the incrustation, on the crowns of the trees intended to bear lac, in order that as soon as the young brood swarm out they may find young and tender shoots to attach themselves to and may not all drop off on to the ground.

"In consequence of the increased value of the summer crop and in order to secure a more plentiful supply then, a larger proportion of the incrustation is often left on the trees in the cold weather than is gathered, which was the case this year (1896)."

Amount of lac collected.—"In the forests, north of Hyderabad, each babul tree, it is computed, yields 7 to 15 seers. The trees on which the insect is found are of all sizes, varying from 1 to 6 or 8 feet in girth; but the insects confine themselves to the young and tender branches only of the trees. One can generally tell a lac-bearing tract, because of the ground underneath each tree being strewn with cut-away branches, the lac from which has been removed.

"The banyan yields the largest quantity of lac, one to two maunds per tree, *sirus* gives one to one and a half maunds, and *ber* about the same

as *babul,* namely, 7 to 15 seers. It is only in the Sekhat forest, a tract about 20 miles north of Hyderabad, that lac is seen on *tamarisk.*"

Mr. Ryan then continues :—

Injuries to lac.—"Fortunately, there are no insects in Sind which attack and destroy the lac, as in other parts of India ; the only injury to which it is exposed being climatic."

"If the rainfall is above the average, as in 1894 (*viz.*, 10·26 inches in Hyderabad), and if floods in the Indus at the same time are very heavy, the excessive moisture in the soil and atmosphere brought about by these conditions affect the crop somewhat injuriously. A moderately moist season seems the most favourable for the propagation of the insect. But conditions are so very unsettled, owing to the vagaries of the river caused by the present embankment system, that no seasons scarcely are now alike. A contractor, who makes a large profit in one year and who pays Government a better price for the next season's crop in expectation of another good crop, probably loses a large quantity of his preceding profits by a failure of the subsequent crop."

Will lac cultivation pay ?—"This is not a difficult question to answer, for knowing the area actually covered by lac and having the value realized from the farm annually, it becomes a simple arithmetical calculation. The area under lac in the forests of the Hyderabad Division is estimated at 2,000 acres, and the value realized in 1895-1896 is R7,560, which gives a net return of R3-12-0 per acre, or more than timber and firewood or cultivation.

"It would be advisable under the circumstances to cultivate lac, and to set apart a certain area in each forest for maintaining an annual supply, and when it is found that the firewood and timber demand can be fairly met, the area under lac might further be augmented.

"In the Jerruck Division the lac-bearing area has been excluded from the working-plan, and the same arrangement might be adopted for Hyderabad as well as forests in the Thar and Parkar District. It is a mistake to suppose that the depredations of the insect in Sind damage the tree on which it subsists to any appreciable extent. This would be the case probably in regions where the rainfall was moderate and where forest growth owed its existence to rain ; all or a very great deal of the life blood, *i.e.*, sap, would soon be extracted by the multitude of insects on the branches in such localities, and in time the tree would possibly succumb. In Sind, however, there is so much moisture in the subsoil, in the riverain reserves especially, that the *babul*, in spite of the tax which

it has to pay in the shape of extraction of sap, and constant lopping of small branches, does not seem to be much injuriously affected. Most of the lac-bearing trees are useless for timber, but they are nevertheless very huge, being 6 to 8 feet in girth with a splendid leaf canopy. There are forests in the Hyderabad District which have been yielding large supplies of lac for the past twenty-eight years and more without any apparent injury to them.'

3. Punjab.

In the Punjab the lac insect is universally distributed and there is scarcely a district which does not contain samples. It is cultivated to a small extent in the Guzerat District, and apparently more extensively in Amballa, Jullundur, Hoshiarpur, Gurdaspur, and part of the Kanjra District. The chief trees it affects are Ficus religiosa, Butea frondosa, Zizyphus jujuba, and Acacia arabica, also species of Ficus.

The product is collected as stick-lac twice a year, in April-May and October-November. The lac-bearing twigs are cut off before the larvæ swarm and dried, and the lac is then scraped off and packed in gunny bags for export. In this state it is generally impure, being mixed with dirt, scrapings of bark and wood, etc.

Private owners of land on which suitable trees grow lease them for the cultivation of lac. Lac collected in the Punjab appears to find its way to Hoshiarpur and Amritsar whence portions go to Mirzapur and a little to Multan. The quantity imported annually into Hoshiarpur is said to be 3,000 to 4,000 maunds. Punjab lac is said to have the reputation of being of inferior quality.

The Zizyphus jujuba lac is the commonest. It is much produced in the Jhang and other districts where tracts of waste land are covered with wild Zizyphus jujuba plants.

Mr. W. Coldstream, I.C.S., has some interesting notes on lac in the Hoshiarpur and Gurdaspur Districts in the *Indian Forester* (Vol. VI, pages 218, 219) :—

"The District of Hoshiapur is a submontane one. Lac is produced in all parts of it, at least in the plains and in the valleys between the hills, in the latter of which it is most abundant. There are two seasons for production, February to April and July or August. The crops are collected in June and October or November. The same tree is said not to produce two crops in the same year. The autumn or October crop is con sidered the more valuable of the two." "The artificial propagation of lac, Mr. Coldstream wrote," seems to be understood by very few persons, but

seems to be occasionally practised and is quite easy to do on the Zizyphus. There appeared, he says, to be a great dread amongst the people lest the spread of the insect should injuriously affect the tree—a fear which is probably quite without foundation. He also notes the fact that many disputes occurred in the civil courts between landlords and occupancy-tenants as to the rights of the latter to take the lac from trees growing on the estates."

On the subject of road-side trees he wrote: "The crop of lac on road-side trees is sometimes sold by Government to a contractor who is allowed to cut off twigs and branches of a certain thickness.

"Of lac in the Gurdaspur Division there is abundance. It appears chiefly on the Albizzia Lebbek (sirus) and Zizyphus jujuba trees, the insect in the course of time ruining the tree. A great deal of lac is collected during the months of January and February in the Barion Bagh near Dinanagar, and as much as R 450 to R 500 a year is obtained for it. The trees are lopped and the branches, after the leaves have been beaten off for fodder, are collected and the lac scraped off."

4. United Provinces and Oudh.

The lac industry in these provinces is worked by Manihars who take two crops a year from Butea frondosa, Ficus religiosa, Albizzia Lebbek, Schleichera trijuga, and Acacia Catechu. Land-owners who possess such trees are careful not to allow them to be felled, and foster the industry as much as possible.

Lac is collected in small quantities near Rurki and Pathri where there are numerous Butea frondosa trees scattered about the cultivated lands. The lac is cultivated to a certain extent by the villagers, but is not cultivated systematically on a large scale. The trees are lopped twice a year in July and October, sufficient brood-lac being left for the purpose of keeping up a sustained yield. The produce is taken to Saharanpur, Rurki, Jawalapur, and Deoband, and sold to workers there in various industries.

5. Central Provinces.

Lac is grown in most of the districts of the Central Provinces on trees in villages and in the waste lands and Zemindari forests. The method of procedure is not usually as scientific as that now carried out in the areas managed by the Forest Department, but a very large sum of money is derived from the cultivation of lac in the district areas. It will be unnecessary to recapitulate here what has already been written about lac cultivation in these provinces.

6. Berar.

Lac has hitherto received but little attention in the Berar districts, although there appear to be facilities for extending the cultivation of this valuable product, and it has been estimated that the sales of lac, if the question were taken up, would rise to many thousand rupees per annum in a comparatively short period.

7. Bengal.

Practically all the lac grown in Bengal is cultivated or obtained from Chota Nagpur and the Santhal Parganas, the chief supplies coming from the latter district and the Chota Nagpur districts of Lohardagga, Birbhum, Singbhum, Manbhum, Hazaribagh, and Palamau. The lac business may be said to be one of the chief industries of these districts.

The insect is cultivated in all the sub-divisions of the Santhal Parganas, but perhaps most extensively in the Dumka Sub-Division. Haripur, the market town of the taluk Kesri, was the birth-place of the trade which attained dimensions quite unknown in other parts of India. Throughout the district, with the exception of Pakour, lac has hitherto been only cultivated on the Butea frondosa. In the latter place the cultivation is principally carried on on the Zizyphus jujuba.

In the neighbouring district of Birbhum the insect is chiefly cultivated on the Ficus religiosa, but the lac is of inferior quality to that obtained from the Butea. The crops are gathered from the middle of March to May and middle of August to October, the crops being called *Jeyth* and *Kartick*, respectively. The March to May crop yields the best and most abundant lac. The seed-lac is removed from the branches when the insects have swarmed from it and is called *Phunki*. *Phunki* is considered to make better shellac than that picked *before* the larvæ have swarmed. It is said that all castes have now taken to lac cultivation. In Lohardagga almost every ryot owns or hires a few Schleichera trijuga or Butea frondosa trees on which he breeds the lac insect. Stick-lac is also gathered from the forest-clad parganas to the south, west, and south-west of the sub-division. In Palamau and Hazaribagh lac cultivation is carried on over about 1,000 square miles in the protected forests which are under the management of the civil authorities. Butea frondosa trees are common in every village and are specially kept by the inhabitants for growth of lac. The Divisional Forest Officer, Palamau, writes :—" There are two kinds of lac, *Kosomi* and *Porasi*, grown respectively on Schleichera trijuga and Butea frondosa. The Kosmo seed-lac is attached to the trees in July or August and becomes ready in the following November when

part of it is cut and collected for the market, a small quantity being left on the trees for seed from which the insects emerge in January. *Kosomi* seed is attached to trees twice in the year and it is collected for the market three times in the year, *i.e.*, sown in January and July and collected in January, July, and November." It is probable that the January collection consists merely of the *Phunki* lac or empty seed-lac. *Porasi* lac is cultivated in October and November and collected in April, a small quantity being left for seed. *Porasi* lac is collected twice in the year—October or November and again April. Palamau lac is chiefly exported to Mirzapur in the United Provinces.

8. Assam.

Lac is reared in a varying extent in almost all of the districts of the province. Kamrup and the northern parts of the Khasi and the Garo hills bordering on the Brahmaputra valley are the chief seats of the cultivation. In Kamrup lac-rearing is chiefly confined to the south bank of the Brahmaputra. The bulk of the lac exported from the district is, however, obtained from Garos inhabiting the northern slopes of the Khasi hills who bring it down to the weekly markets at Palasbari and Chhaygaon and Boko. A small quantity is also brought down by Bhutias to the annual cold weather fairs at Darranga and Subankhata in the north of the district.

Very little lac is reared in the remaining districts of the province. None is produced in the *sade* sub-division of Goalpara. Some is produced in the North Cachar hills and Manipur. It is not known how much lac is produced annually in the Districts of Durrang, Sibsagar, and Lakhimpur. The Deputy Commissioner of Durrang reported that some years ago the lac-rearing industry in his district was ruined by a blight which destroyed the insect. It is still reared to a small extent by Caharis in the north of the Mangaldai Sub-Division. Very little rearing is done in Sibsagar, but some is still done, however, in the Golaghat Sub-Division.

Lac-rearing is said to be unknown in Nowgong and the Naga hills. In the years 1896-97, 1897-98, and 1898-99 the exports of lac from Assam were 16,525, 24,869, and 14,494 maunds, respectively.

The method of propagating lac in Assam is practically the same as in Bengal. There are usually two crops in the year, one being collected in May-June and the other in October-November. In Sylhet the first is called the *Aus* or early crop, and the second the *Aman* or late crop. The first crop is mainly used for seed purposes; the second is the chief crop and supplies the bulk of the exportable article. It is said that a Ficus altissima tree will grow lac for three to four years in succession, whilst others

have been known to produce lac for ten to twelve years without rest. A good-sized tree will yield from 30 seers to 2 maunds of stick-lac.

Mr. McKee when Conservator of Forests stated that he thought it probable that most of the lac exported from Assam was collected from cultivated crops of Cajanus indicus.

9. Madras and Coorg.

Lac is produced in comparatively small quantities in Madras, apparently owing to the fact that the industry of ornamentation with the product is but little understood. It is produced to a small extent in Kanara and Malabar on the Shorea Talura, the crop being collected from the middle of October to the middle of November, whilst the seed-lac is propagated from about the middle of March to the middle of April.

10. Burma.

Very little lac appears to be collected in the districts in Lower or Upper Burma. This is curious, for from old accounts extant it would seem probable that there was a considerable export of Pegu lac three centuries ago. That the industry could be worked up in Upper Burma and a highly lucrative trade organized appears probable.

At present the only information of importance available from a district comes from the Pakokku Chin Hills. The valuable report dated 29th August 1906 on the subject of lac cultivation and collection by the Assistant Superintendent is given in full below :—

" The lac industry in these hills is most important and should be encouraged by every means. Last year from one set of villages alone more than 10,000 viss of lac was exported and large amounts were exported from other parts of the hills.

" The lac here is usually picked off the trees about the end of October and sold to local merchants at the foot of the hills at R1 per 3 viss if undried, R1 per 2 viss dried.

" I have arranged to obtain samples of the lac as gathered from three different trees, and also a sample of the lac after swarming. I should like to have further information regarding the times of swarming of the larvæ and the winged males.

" The local merchants will only buy the coloured lac from the producers, and until the demand for the colourless lac is formed it is hopeless to expect the people to change their method of collecting it. The local market can only be taught by the requirements of the big

traders who buy up the local produce imported into the towns. So that the points raised (by Mr. Stebbing) can be answered as follows :—

(*a*) The people do still gather the lac before swarming.

(*b*) If there was any demand for colourless lac at the foot of the hills the people would very soon learn to wait till after the swarming, as it would pay them better.

(*c*) The experiment would, I think, be easily made; the lac here is cultivated on trees below the level of the pine trees, about 3,000 feet."

(*d*) IN NATIVE STATES.

1. Bombay.

Lac is said to be produced largely in the forests of the States of Ali Rajpur, Udepur, and Deogad Baruja. The chief lac-yielding trees are Ficus religiosa, Butea frondosa, Zizyphus jujuba, and Schleicher a trijuga.

2. Central India and Rajputana.

Rewah and Nagod are the two chief lac-producing States of Central India.

In Rewah the cultivation has been pushed to a very great extent, with the result that a net revenue amounting to no less than 2 to 4 lakhs a year is obtained. The Butea frondosa upon which $\frac{9}{10}$ths of the lac is cultivated has been made a royal tree, and its felling is prohibited. The remaining lac collection is done from Schleichera trijuga. Lac collection takes place both from the forests and the district lands outside. Rewah is far ahead of other States in this work.

In Nagode the lac cultivation is confined exclusively to the Butea frondosa. This State is under British supervision and the industry has recently been developed on good lines. No restrictions have been enforced against the felling of Butea frondosa trees in the fields. A net revenue of R6,000 per annum is now obtained from the industry in this State.

In both States they confine themselves to propagation after the rains (September 15th to October 15th), finding apparently that the insects are less liable to suffer from frosts than from heavy rain and prolonged breaks in the early monsoon in June. This period is for the Butea frondosa. The season for propagation on Schleichera trijuga is later. The produce is always sold by the Forest Departments of the States in the crude condition. In several States efforts are now being made to establish or extend the industry, but matters have not progressed far as yet.

The Conservator of Forests, Punjab, states that the insect is cultivated in Rajputana, but he was unable to afford any details on the subject.

3. Hyderabad.

Lac cultivation would appear to be a paying business in parts of Hyderabad. The information collected upon the subject has been detailed when dealing with the district lands in Sind above (page 47).

4. United Provinces and Oudh.

Lac is cultivated in the Ekowna Forests on the Kapurthalla Estate. The trees used are the Ficus religiosa, Butea frondosa, and the Schleichera trijuga. These trees are not allowed to be felled and the industry is fostered as much as possible.

5. Madras.

Lac is cultivated on the Jeypur Estate in the Vizagapatam District. It is cultivated chiefly in the northern part of the Omerkote Range and tana over an area of about 200 square miles, but chiefly in the north-east corner of the tana and range which occupy the north-west corner of the estate. Lac is also cultivated in the north-east corner of the Nourangapur Range and tana, all of which lie in the Government taluk of Nourangapur.

The insect is reared exclusively on the Schleichera trijuga although it is found wild occasionally on Butea frondosa and other trees. It is cultivated chiefly on trees on waste lands near villages for the sake of convenience, the trees being spared for the purpose. Little or no lac is found in the reserves, which consist chiefly of sal trees.

The collection is never done departmentally, but always by the ryots. Two attempts were made to cultivate lac departmentally, but without success. Formerly the ryots were charged a royalty of R1 per tree for the cultivation of lac; a royalty of 12 annas per maund was also collected when the lac was exported, which was paid by the merchants. About R10,000 used to be realized as a tax on trees and royalty on lac exported some ten years ago. The tree-tax, however, was found to press hard on the ryots since it had to be paid yearly and before the lac was disposed of, and consequently the revenue fell to below R2,000. The tree-tax was abolished and smuggling prevented, and the revenue has now risen to R4,000. The right to buy the lac was farmed out to the ryots, their interests being safeguarded by fixing for each year a maximum rate per maund to be paid by the purchasers to the ryots. The ryots were informed that the tree-tax was abolished and have been encouraged to extend the cultivation. A difficulty still exists, however,

in the fact that the Schleichera trijuga is not a prohibited tree and it is consequently being heavily felled, as it is a useful timber tree. In the interests of the industry all trees of under 2 feet should be prohibited from being felled.

6. Mysore.

In Mysore lac is produced in all three Divisions of the State, but chiefly in Nundidroog, and it is found most commonly on the Shorea Talura. The insect thrives well in Mysore and it might by cultivation be raised to any extent on trees growing on barren soil which would otherwise yield no return. The Carob tree will probably be found well adapted for this purpose. It will flourish in dry and stony places, and the lac insect thrives on it.

Mr. J. Cameron in his "Forest Trees of Mysore and Coorg" wrote: "The lac tree (Shorea Talura) of Mysore is confined to the deciduous tracts of the Maidan. It is abundant in the Anekal, Closepet, and Nundidroog taluks, where the propagation of lac has been actively taken up by the Forest Department. In the Anekal taluk the Assistant Conservator is extending the propagation of both the tree and the insect very rapidly. Lac being in great demand, this action cannot fail, in the course of a few years, to largely increase fresh revenue."

7. Travancore.

The Conservator of Forests reports that lac is only collected from one range in unreserved forests. No area can be said to be under lac and the insect is not propagated. Wild lac is collected from Odina Wodier, Ficus religiosa, Careya arborea, and Spatholobus Roxburghii by the local inhabitants, under minor forest produce contracts. The revenue obtained is very trifling and cannot be estimated. No steps are at present being taken to increase the yearly amount of lac obtainable from the forests.

CHAPTER X.

EXPLOITATION.

(*a*) COLLECTION.

It has been already shown that the method of collecting the lac usually adopted is to break off the branches containing the incrustation before the young larvæ have swarmed. This naturally results in the lac cells

still containing the now useless red liquid known as lac-dye. Dr. Hooper's analyses given on page 68 have, however, proved that this dye is still present in the lac, in the pores of the skins of the dead female insects, after the larvæ have swarmed. The so-called 'phunki' lac is brood-lac from which the young larvæ have swarmed. It is collected as soon as the whole of the larvæ have issued. The term would seem to be open to considerable misapprehension or misinterpretation as Dr. Hooper has shown* that so-called 'phunki' lac examined by him contained a considerable amount of red dye.

(b) PREPARATION FOR SALE.

The twigs and branches on the trees bearing the lac incrustation are broken off and sold as they are to the middlemen who take them to the factories. In some localities the incrustation is broken off the branches, the latter being left *in situ* on the tree. Or the branches are broken off and the lac incrustation detached, by hammering with wooden mallets and disposed of in this condition.

(c) TREATMENT IN THE FACTORY.

In the factory the lac-bearing twigs and branches are broken up into short lengths which are termed stick-lac. This is effected by hand or machinery. This stick-lac is then crushed either in ordinary grain mills worked by manual labour or by rollers driven by machinery. The substance obtained is then softened and separated into three different masses consisting (1) of fragments of the branches and twigs which are often used as fuel; (2) fine dust which consists of minute fragments of lac and dirt which is technically termed *Khud*; this is sold to the makers of bangles and toys; and (3) granular lac known by the trade name of seed-lac.

The seed-lac is washed by being soaked in water for some twenty-four hours. The lac cells are then broken up, the seed-lac being reduced to a smaller and a more uniform granulation. The water during this process becomes a deep purple claret colour. This is the lac-dye which is now a waste product. During the reduction of the lac 'cells' to the granular form a fine powder is obtained which consists of dirt and minute particles of lac. This is dried and sold under the name of *Gand* and is utilized for the manufacture of lac bangles.

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* Gathering of lac, *Indian Trade Journal*, IV, 47, page 383.

In some parts of India, and more specially where lac factories do not exist, different methods of preparing the lac required for local use are in force.

In the Punjab the lac is boiled in water containing crude carbonate of soda and borax, or it is well rubbed in water containing a little alum and is then strained through a cloth, fresh water being added until all the lac-dye has been washed out. In Hyderabad it is scraped off the twigs, dried and ground in a mill stone. It is then mixed up in potash and water and then dried in the sun. It is still a moot point whether these native methods of chemically treating the lac do not spoil the resulting shellac.

It will be seen that these troublesome but necessary processes of washing the lac incrustation (since the dye has no longer a commercial value) are entailed to get rid of the red colouring matter, and the question which has been propounded by manufacturers is whether the larvæ should not be allowed to swarm before the removal of the twigs in order to do away with the washing processes. Analyses have shown that the stick-lac still contains a certain amount of colouring matter even after the larvæ have swarmed.

(*d*) MANUFACTURE OF SHELLAC, BUTTON-LAC, AND GARNET-LAC.

After being washed the seed-lac is exposed on drying floors to the atmosphere and light by which it s thoroughly dried and to some extent bleached.

The lac is then often mixed with orpiment (yellow arsenic) or resin, or with both. The former makes the lac opaque and imparts to it a rich pale straw colour and is used for the manufacture of shellac, but not in that of garnet, button, and the other grades where paleness is not required. The resin serves to lower the melting point which is desirable and the use of a certain amount is therefore recognised as a necessity in the manufacture of shellac. Owing to the cheapness of resin it is often used to unduly adulterate the shellac. Two to five per cent. is the normal amount permissible.

The orpiment is ground to a fine yellow powder and then mixed with the seed-lac and the necessary amount of resin, and the whole mixture is then placed in very long narrow cloth bags 10 to 12 feet in length and 2 inches in diameter. After the bags have been charged they are conveyed to the furnace held over open coke and charcoal fires and slowly twisted up. The heat melts the lac and the squeezing of the bag causes

a continuous oozing from the portion exposed to the fire. Every now and then one end of the bag is given a reverse twist which causes the portion from which the lac has been squeezed out to coil up like a rope. The bag is drawn steadily forward as portion after portion is exhausted until all has been emptied. The lac drips from the bag to the floor beneath the fire. Portions not sufficiently melted are scraped up and remelted. The melted lac now requires to be stretched into thin sheets and this is done by stretching it out whilst still molten. This operation is carried out in various ways dependent on the degree of up-to-datedness employed in the preparation of the shellac. The thin sheets are then examined for impurities and all dark coloured or dirt-impregnated portions are broken out and the rest separated according to purity and shade of colour.

The various qualities of shellac are known to the trade as 'Fine Orange D. C.,' 'Livery,' 'Native Leaf,' etc .

No portion of the lac is regarded as useless. The parings and fragments of every stage in the manufacture of shellac are thrown back on to the floor of the melting furnace and again melted and made into fresh sheets. All portions found unsuited for the manufacture of shellac are used in other industries. For instance, certain qualities squeezed from the melting bags are dropped on to smoother surfaces and dried in circular masses an inch and a half in diameter and form the 'button-lac' of commerce. Only the finer qualities of seed-lac are made into shellac on account of their paler colour. The more highly coloured lacs are made into thick dark-red sheets, known as 'garnet-lac.'

After the melting has been completed the bags are boiled in order to remove the residuary matter which is known as *Kiri* or *Phog*. From this two qualities of inferior lac are made. These two substances are formed into thick circular slabs, about six inches in diameter and an inch in thickness. In this form they are sold to the makers of sealing-wax, bangles, and other similar articles.

When steam power is made use of the processes of preparation differ mainly from the native factory ones in rapidity and mangnitude of production.

CHAPTER XI.

STEPS NECESSARY TO IMPROVE THE CULTIVATION OF LAC.

There can be little doubt that improvements are possible in the present methods of lac cultivation. Those initiated some years ago in the

Central Provinces and now successful in the Raipur Division require to be more widely known and introduced into other parts of the country.

The chief improvements required to be made are in the direction of the formation of regular areas of coppice, either from seed or cuttings, which should be worked on a definite rotation.

The particular trees made use of would vary with the locality, and experiment is required to find out which of the species would coppice best, *i.e.*, which would give the largest and strongest stem capable of supporting the lac insects in the shortest space of time, and what is the best rotation to work these stems on.

Information is also required on the subject of the capabilities of the various trees to be grown from cuttings and the number of years in which such cuttings can be made to yield a crop of lac and for how long they will continue to yield a full one. It is said that Ficus infectoria will bear a crop after three years.

Experiments are also required to be made with such shrubs as *Cajanus indicus* (*arhar dal*). It is reported that this latter plant if sown in November in Assam will be fit to plant out at the close of the following rains, the plants being by then stout saplings averaging four feet in height. Planted in rows 4 feet by 8 feet apart (1,360 to the acre) it will, if well cultivated, be ready to receive the insect exactly two years after first sowing. If this is really the case, and experiments will easily demonstrate the truth of the statement, it is almost inconceivably surprising that the cultivation of lac has been so neglected in the Province of Assam. Further, it is stated that lac reared on Cajanus indicus, which is said to be the best lac produced in Assam, can be put on to other lac-rearing plants such as Ficus cordifolia, Ficus comosa, Ficus elastica, Ficus religiosa, Zizyphus jujuba, and Ficus altissima. Crops of lac on the *arhar dal* could thus be raised in nurseries in the forest from which the seed-lac could be put out on to trees in the forest or distributed to the inhabitants of forest and other villages. The formation of these lac-nurseries is strongly to be recommended in Assam, and in fact in many parts of India, with a view to demonstrating their usefulness to the people and thus improving the methods of collection and increasing the amounts available for export. One of the means by which the Department will be enabled to largely develop the lac industry in many parts of the country besides facilitating their own work, will be by the formation of forest villages inhabited by people who, undertaking a little cultivation sufficient to enable them to supply their requirements in grain, devote the rest of

their time to forest works, amongst which the cultivation of lac might take a prominent part.

On the subject of State forest cultivation of lac Mr. McKee's often-quoted paper to the *Indian Forester* (1876, page 26) has attained the position of a classic upon the subject, and the following paragraphs are as much worthy of consideration now as was the case when they were penned.

Discussing the question of State cultivation Mr. McKee wrote :—

"With regard to the cost, this will necessarily vary with the description of the trees employed for the purpose, and the proportion they bear to one another in numbers on a given area. Such trees as *Palas* (Butea frondosa) and *ber* (Zizyphus jujuba), which are of comparatively small size, and which are found in many places in a state of almost pure forests, will necessarily cost less to bring under cultivation than larger species such as *Kusum* (Schleichera trijuga), *Guler* (Ficus glomerata), and *Pipal* (Ficus religiosa), which are generally found either scattered about the forests or fringing the slopes of ravines and the banks of the rivers, for less brood-lac wi l be required for their treatment and less trouble and time employed in searching for them ; but, on the other hand, the larger outturn obtained from the latter species will more than repay the extra money expended in preparing them. Our experimenst extend at present to having operated on 7,467 trees of the *Palas* and smaller species and 1,903 trees *Kusum* ; these numbers represent the standards on which the insects are doing well and do not include a large percentage which turned out failures. The total cost of bringing the above under cultivation including all charges, such as collecting brood-lac attaching it to the trees, etc., average R3-5-11 per 100 trees of *Palas* and R15 per 100 trees of *Kusum*.

"Owing to the dryness of our summer and the great damage to the lac caused by the hot winds it does not seem probable that we can look forward to even two good crops in the year ; the summer one will probably in almost all places, except those where favourably situated, be of poor quality and quantity of lac developed not more than sufficient to leave on the trees for producing the crop which matures during the cold season. This latter will generally be good and must be the one we depend on for a return. Reckoning, then, on only one crop a year, and estimating the yield per tree at the moderate quantities of 3 seers for *Palas* and 15 seers for *Kusum* or trees of like size, we obtain a net outturn, after deducting 25 per cent. for wastage in drying and packing, for the *Palas* and small

trees of maunds 5·25 per hundred trees, and from the larger species of maunds 27·32, which, if valued at R15 and R20 per maund, respectively, will be worth R84-6 for the former and R541 for the latter. Take from these sums the cost of producing the article, which in future will be, if anything, less than heretofore, owing to the lac being obtained in one spot and the net profits on 100 trees of *Palas* will equal R81 and on the same number of *Kusum* R526. Large areas of forests are now available on which the number of *Palas* and other suitable trees per acre quite equal or even excel the above unit, and the expediency of forming plantations of *Kusum*, which area for area would yield a more valuable crop, is under consideration."

Mr. McKee gives a list of seventeen trees as those on which the lac is generally found. These have been included in the list given in Chapter V, which represents the food plants of the whole of India.

Mr. McKee then remarks:—"Of the above trees the light golden resin obtained from the *Kusum* is the finest, as from it the most valuable orange shellac is manufactured, and next in quality is that obtained from the *Palas*, which yields the garnet-lac of commerce. Wherever possible, therefore, the *Kusum* tree should be chosen for standards; but as the *Palas* is generally found in much greater numbers, area for area, its produce will nearly compensate in quantity for the reduction in its value. Having selected the forest for experiment, the next point to fix on is the local date on which the insects leave the parent cells, a step of great importance, and one on which the first success of the plantation will very greatly depend, as, should the work of gathering brood-lac be delayed until visual proof of the exit of larvæ is obtained, a vast quantity will be killed in the operations of collection, transport, and of tying the incrusted twigs on the standard selected for nurseries." The date of evolution having been fixed on with some certainty Mr. McKee describes the procedure necessary to put the brood-lac upon the trees which has already been discussed. On this subject he continues:—"When attaching twigs it appears necessary to take care that the wood of the standard is not of denser composition than the wood of the tree from which the brood-lac is gathered, as it is believed that the larvæ reared on soft-wooded trees are comparatively weaker than those which are found on species of harder texture. There is an idea prevalent among the *Gonds* that nursery standards must be prepared with brood-lac taken from the same species as themselves; but this has been proved to be incorrect. The brood-lac yielded by the *Kusum*, a very hard-wooded

tree, appears best suited for propagating purposes as it succeeds on trees of all other species. When several trees of the selected species grow together it does not appear necessary at first to artificially cultivate more than three-fourths of them, as during the succeeding evolution the remaining fourth will almost certainly be brought under preparation by natural means,* but as the success of the crop depends principally on the supply of juices obtained by the female insects during the period they continue to deposit the resin, it is necessary to place the brood-lac on the youngest and most sappy branches.

"Lac preserves may be formed by carrying out the above simple operations; but it is not probable that success will be attained at once or until experience has drawn attention to several peculiarities in the habits of the insect and the manner in which it is influenced by situation and atmospheric conditions. Our first attempts were made in the cold weather of 1874, but owing to the want of knowledge that prevailed on several essential points, both among the superintending staff and the labourers employed on the work, the extent of these was naturally limited and of small result. It was not known with any certainty when the exit of young larvæ commenced or what was the best method of applying them to the trees; thus a large number were lost and this destruction of insect life was greatly increased by the rough handling they were exposed to by the workmen. In one instance a plantation which had been prepared and was progressing well was nearly destroyed by mistaking an evolution of male insects for one of larvæ,—an error into which it would not be possible to fall except through want of knowledge of the insect's habits; in another the colonies were greatly damaged by a fire which broke out and destroyed the lac on all but the highest trees; while in a third, frost and hot winds killed the females and stopped the formation of lac on nearly half the number of trees prepared. But although we had to contend with so many mishaps, partly through ignorance and partly from physical causes, each experience in its way brought valuable information which will render more certain our future undertakings.

* "In 1874, 1,300 trees were prepared at Kosait in the Satpura Reserve, in 429 of which the lac was destroyed during the hot weather of 1875, leaving 871, from the incrustations of which a new brood of larvæ swarmed in July 1875. The lac on these trees was not touched owing to its being a bad crop, but was left for further propagating purposes. On the 19th August, however, an enumeration of the trees on this spot proved that new lac was then being formed on 1,380 trees; thus 509 trees must have been affected by their proximity to the old standards."

"Of the points to be noted in making these preserves, the one of the greatest importance perhaps is the fact that the lac incrustations may be plucked several days before the larvæ appear,—a knowledge of which will enable a larger number of trees to be prepared during the working season than if it was necessary to delay the operations until the evolution actually took place, as, owing to this latter being nearly simultaneous in and about one locality, the period for forming the plantation must be necessarily limited to the number of days it takes the cells to become empty; besides which, by attaching the lac twigs before the birth of the larvæ great numbers are saved, which would otherwise perish during the process of being attached to the trees. In support of this fact it will be interesting to give the following observations:—Mr. Thomson, Deputy Conservator, in order to fix on a safe date for gathering the brood-lac, caused twigs, covered with the incrustation to be brought in from the surrounding forests every two days for examination. These he labelled, dated, and hung up in the verandah of his forest bungalow; the first twig was gathered on the 10th June and the others on every succeeding alternate day until the 12th July. These twigs were the produce of several trees, and were brought from various parts of the forest within a radius of 10 miles; some were plucked from the Guler, others from the Pepal, but the majority from the Palas. On the morning of the 13th July, according to custom, Mr. Thomson examined the twigs, but found no sign that the larvæ had vacated their cells, although microscopic observations had proved them to be fully developed. On the 14th, however, an inspection showed that on all the twigs without exception the young were pouring out of the cells through the anal apertures; thus the twig gathered on the 10th June hatched exactly on the same date as the one gathered on the 12th July, or more than a month later." "While on this subject it is necessary to draw attention to the reported variation in the number of evolutions and consequently in the number of crops which are obtained in different countries. In Mysore and Burma it would appear that three evolutions of the insects take place during the year."

Discussing the influence of climate Mr. McKee says:—

"This no doubt is the reason why in districts where the seasons are dry and where showers are of infrequent occurrence during the hot weather, the summer crop is invariably poor and scarcely worth collecting. Moisture is one of the great essentials for a fine crop of lac, and many disappointments if not total failure will result by fixing on dry arid

spots for the formation of the plantations. The females cannot obtain sufficient nourishment at this period from the sapless stems, and their death will be recognised by the pitted appearance assumed by the cells, the crowns of which fall in as the insect contracts within them, and by the cessation of the growth or dissappearance of the white filaments which obtrude from the spiracular orifices. Species such as Kusum and Guler, which most frequently are found growing along the banks of rivers, where the atmosphere is humid and moist, are, for these reasons specially adapted for yielding good crops of lac ; while the Palas offers advantages, as its sap-producing functions are actively employed during the hottest season of the year when it forms both new wood and leaves."

CHAPTER XII.

STEPS TO BE TAKEN TO IMPROVE THE COLLECTION OF LAC.

1. Should lac be collected before or after swarming of the Larvæ.

It has been shown that definite periods, varying from May to June and October to December for the two broods, respectively, are commonly accepted in various parts of the country as the correct times to collect the lac. These periods of collection, based upon sound and close observation at the time of the first cultivation of the insect in a remote past, have up to recently been the correct ones. Before lac itself, *i.e.*, the incrustation of the insect, came into use in India the red dye was in general demand and therefore it was necessary to collect the lac incrustation *before* the young larvæ swarmed out, practically carrying the major part of it with them. Even after the lac incrustation came into general use there was still a large demand for the dye and therefore the custom of collecting the lac twigs before swarming remained the correct cultural one. We have seen that Europe imported lac-dye from India long before she took the shellac itself. Thus the period of collection fixed in remote times was in the course of time accepted by the European middleman who bought from the actual collector, and by the factory owner as the correct one, and rightly so.

With the general use of chemically made aniline dyes the demand for the lac-dye decreased until it has now become an almost negligible quantity. The old methods of collection, however, still continue, with the result that the manufacturer has still to go through the whole process of removing the dye from the stick-lac before he can make any use of the latter, although the dye thus obtained is practically useless and worthless. This has naturally given rise to the question—Is it necessary that the lac should reach the manufactory still full of the lac-dye ?

This question has received considerable attention of late and has now, I think, been settled by definite experiments and Dr. Hooper's carefully made analyses. Analyses of larvæ submitted in a living state to Dr. Hooper have shown that they themselves consist in the dried state of 48 per cent. of pure colouring matter after having lost 54 per cent. of water in the drying process. Acquaintance with the life histories of other similar scale insects in which, after the production of eggs, the mother dries up to a small piece of wrinkled skin naturally led one to infer that on the exit of the larvæ the skin of the lac female would dry up and lose all its colouring properties. This, however, is unfortunately not the case. Two sets of samples of so-called phunki lac from which the larvæ had issued were submitted to Dr. Hooper. The first had been plucked from the tree (in the Saharanpur District) before the larvæ swarmed and was submitted to Dr. Hooper a couple of months after the larvæ had swarmed out and died on and round the branches. The percentage of dye was 3·5 per cent. The second set of branches were cut from the trees in Raipur by Mr. Lowri *after* the larvæ had swarmed out of them *on* the trees. The percentage of dye still in the lac was found to be 1·4.

Mr. Hooper's own experiments with branches of phunki lac gave the percentage of dye present at 3·6 (Nani Tal lac) and 1·8 (Kheri lac).

The question to be decided therefore would seem to be whether since all the dye does *not* disappear with the swarming larvæ, it would be any cheaper for the manufacturer, so far as the washing processes he has to put the lac through are concerned, to have the lac picked before or after the larvæ have swarmed. It would seem probable that the saving in cost by picking after the larvæ have swarmed, if any is possible owing to the lighter washing required, would be more than counterbalanced, so far as the lac cultivator is concerned, by the greater risk of deterioration to which the lac is exposed during the extra period it must be left on the

trees to wait for all the larvæ to issue—a period reaching to nearly a month.

2. Dr. D. Hooper's Analyses.

Three carefully selected samples were submitted to Dr. Hooper for analysis, as follows :—

(*a*) Young living larvæ which had swarmed out of the cells of lac growing in the Raipur Forests, Central Provinces, during the last week of February 1907.

(*b*) Stick-lac from which the larvæ had swarmed in November after the lac had been plucked. This lac came from the Saharanpur forests in the United Provinces.

(*c*) Stick-lac from which the larvæ had swarmed in February before the lac had been removed from the trees. This lac came from the Raipur forests in the Central Provinces.

The questions put to Dr. Hooper were :—

(1) Do lac larvæ consist almost entirely of what we know as lac-dye ?

(2) Does the lac incrustation sent contain lac-dye, and if so, in what proportion ?

Dr. Hooper's analyses and remarks were as follows :—

(*a*) *Analysis of the young living larvæ.*—" I received your most interesting samples of lac larvæ. They were all alive and well when they arrived, and I at once commenced to subject them to the process of chemical analysis. The larva lost 54 per cent. of water when dried to constant weight in the water even at 100°C. The dried larvæ contained approximately the following main constituents :—

Wax and fat	1·5
Soluble colouring matter	48·0
Insoluble albumen	42·0
Ash	8·5
	100·0

" The insects contained therefore about half their weight of red colouring matter, or a ratio of 143 to 100 of albuminous remains. In the analysis of samples of lac given in the paper in the *Indian Trade Journal* the relation of red colour to the insoluble portion was 25, 23, 33 and 20 to 100. These figures are not sufficiently

uniform to be instructive, especially as a so-called *phunki* lac incrustation gave the highest proportion of colour. It will be very interesting to receive what you consider to be empty lac so that we can attempt a chemical method to confirm or otherwise the *phunki* entomological opinion ; so far it seems that the word is very loosely applied and no doubt such lac contains the larvæ before they have escaped.

(*b*) *Analysis of Saharanpur stick-lac from which the larvæ swarmed after it had been plucked.*—I send you the results of the Saharanpur sample of lac. The analysis quite upsets theories formed. The true '*phunki*' lac should contain little colouring matter, but the sample yielded a considerable quantity. This is the analysis :—

Water	2·7
Resin	78·6
Colouring matter	3·5
Albumen	12·9
Ash	2·3
	100·0

"This amount of colouring agrees with the amount found in the '*phunki*' lac supplied from Naini Tal and recorded in the *Indian Trade Journal* and I took all precaution, as you suggested, to remove any dead larvæ and shift out some of the loose particles, which appeared to be dye, before the examination. So far chemistry cannot decide between '*phunki*' lac and lac collected before swarming, unless you can send me further samples of authenticated incrustations. After all the weight of the larvæ escaping from the cells would bear small proportion to the weight of the resinous matter on the branches, and it would seem that there is some other colouring matter to be accounted for which does not come out with the larvæ. I should, however, be pleased to examine further samples before drawing final conclusions."

This other 'colouring matter' which Dr. Hooper considers must be present is no doubt chiefly to be found in the shrivelled skins of the female insects.

(c) *Analysis of Raipur stick-lac from which the larvæ swarmed out while the lac was still on the tree.*—" The sample of lac from Raipur, Central Provinces, collected after the swarming of the larvæ had the following composition .—

Volatile matter	2·3
Resin	90·5
Colour	1·4
Albuminous matter	5·2
Ash	·6
	100·0

" This is a good lac and richer in resin than any other kind I have examined. The ratio of colour to the insoluble albuminous matter is 26·9 to 100, almost the same as that found in the Siwalik sample (27·1)."

From Dr. Hooper's analyses, as given above, it would appear that the swarming of the larvæ from the lac does not remove all the colouring matter from the incrustations and that the washing processes to free the seed-lac from the colouring matter will have to be undertaken under any circumstances.

CHAPTER XIII.

STEPS TO BE TAKEN TO INCREASE THE PRODUCTION OF LAC.

Formerly the lac industry was entirely in the hands of private individuals, the stick-lac being collected from private lands and reserved forests in British territory and from Native States, amongst which latter Rewah may be mentioned as the chief. The right to collect the lac in unreserved forests was sold to the highest bidder, whilst in private lands the large firms interested in the substance obtained leases for a term of years, from five to ten, which enabled them to increase, by cultivation, the ordinary yield.

Somewhere about twenty years ago Government began to turn their attention to this valuable commodity from which, in spite of the large size of the exports, they derived a very insignificant revenue. The Forest Department in the Central Provinces took up the question of the formation of lac preserves, and these have been continued and enlarged up to the present date.

The question has, however, during the last four years or so once again come to the front owing to the remarkable increase in the price of the article and the matter has been receiving the serious attention of the Director-General of the Commercial Bureau.

The rise in price, which has been a natural concomitant of a demand exceeding the supply, is attributed to the extensive use of shellac in electrical work and in the manufacture of gramophone records.

As far as can at present be judged, there appears accordingly no reason why the demand for the product should not continue to increase, and this probability would seem to call for prompt and urgent action both on the part of those already interested in the cultivation and of those who, by introducing it into areas in which it is at present unknown, can thus improve the pecuniary value of the lands and add to the prosperity of the ryot.

The areas in which such action is necessary may be divided into—

1. District Lands,
2. Forest Department Lands,
3. Private Lands,
4. Native States.

1. District Lands.

A list of trees upon which the insect thrives has been already given in the preceding pages and the species specially favoured by the insect in different parts of the country have also been detailed.

Now it is not an essential of lac culture that the insect should be cultivated in groves of trees or forests. The cultivation can equally well be carried out on scattered trees of the proper species in hedge-rows, cultivated lands interspersed amongst scrub jungle, or waste lands. Much of the lac cultivation of the country is already undertaken in such localities. It, however, could be largely extended in areas in which the article is at present unknown, and the attention of District Officers should be drawn to this fact. With ordinary care colonies of the insect, *i.e.*, branches containing lac incrustation from which the larvæ have not yet swarmed, can be imported from lac areas with perfect ease and safety. The chief points to remember when importing the article are :—

(1) Imported lac should be only taken from *trees of the same species as, or species which have a harder wood than*, those growing in the district into which the importation is made and upon which the insect is to be propagated.

(2) The branches containing the lac brood must be picked at such a time as to ensure—

i. That the larvæ will not swarm whilst still *en route* to their destination.

ii. That the brood-lac is not so immature that the branches containing it will dry up, thus killing the females before their eggs are mature and ready to hatch into larvæ.

As has been pointed out, the periods of maturity and hatching out of the larvæ vary in different parts of the country and importers of brood-lac must rely on the experience of those in charge of the lac areas from which they introduce colonies. They must, however, insist on obtaining these colonies from the proper species of tree, or certain failure will be the result of their efforts—a failure which has often been experienced in the past and has led to so many attempts at lac cultivation in areas where it was previously unknown being abandoned, thus bringing into disrepute efforts to establish a valuable industry in areas entirely favourable to its introduction.

iii. Leases given out for lac preserves should not be less than, say, of five years' duration. This is necessary to enable the lessee to undertake the necessary steps for the cultivation of the product.

In Assam the insect lives upon *Cajanus indicus*, and this fact would seem to demand serious attention in this quarter. There appears to be every reasonable hope of a large industry growing up by the careful cultivation of lac upon this plant, which could be grown on short rotations, without the risk attendant on cultivation upon large trees. Lac cultivation on *Cajanus indicus* is said to yield more valuable returns than cotton cultivation.

Lastly, the District Officer can further the introduction of and growth of the industry by encouraging the planting of the best species of lac-bearing trees in his district.

One of the dangers which faces the cultivation of lac in the district waste lands is due to the fact that such areas are annually overrun by fire. It need scarcely be said that lac preserves require to be rigidly protected against fire.

2. FOREST DEPARTMENT LANDS.

Over twenty years ago Mr. J. McKee, late Conservator of Forests, in his article published in the *Indian Forester*, parts of which have been

already reproduced, strongly advocated the formation of lac preserves in the Central Provinces, and his recommendations have since been given effect to.

The formation of lac preserves in the forests is a departure strongly to be recommended in many parts of the country. Many Forest Divisions contain areas of scrub jungle from which little or no income of any kind is obtainable. These areas often contain scattered over them species of trees eminently suitable for the cultivation of lac. Attempts have been made in some localities from time to time to introduce the cultivation of lac into such areas, but more often than not they have been met with failure—a failure due in most cases to a want of knowledge of the life history and to the important points which govern the importation of colonies.

In the formation of lac preserves in an area the first points to be taken into consideration are :—

i. The number of suitable species of lac trees present and the species which are likely to yield the finest lac.

ii. The abundance of the best species of tree or trees present on the area. It is obvious that the closer together these are the easier and cheaper will be the propagation of the insect and the collection of the lac.

iii. The possibility of adding to the number of lac-giving trees by the formation of nurseries and plantations of the species required.

iv. The possibility of raising cuttings of the species decided upon with the object of growing the lac upon these as soon as they have reached sufficient thickness. *Ficus infectoria* cuttings of three years in age are so used in the Central Provinces.

v. It will also be necessary to carefully consider the climate of the locality with the object of discovering the proper period for the introduction of the brood-lac. In some localities, *e.g.*, in Rewa and Nagode Native States, the insect is only propagated after the rains (September 15th to October 15th) as the young insects are less liable to suffer from frosts than from heavy rain. It will also be necessary to ascertain as early as possible the local date or dates upon which the larvæ issue from the lac cells, as upon this being correctly determined will depend the whole success of the future propagation of the insect.

vi. The periods for the collection of the stick-lac will require consideration. In some localities the lac collection is only undertaken

once a year, the other crop being left for propagation, *e.g.*, in the Central Provinces; in Burma and Mysore, on the other hand, it is stated that the insect is propagated three times in the year, and that the lack is also collected thrice in the year.

It will therefore be necessary to carefully examine the crop obtained and ascertain whether it is an abundant one or whether the lac present will only suffice for propagation on the number of trees it has been decided upon to infest.

In collecting the lac two important points must be borne in mind :—

(*a*) That the swarming of the male insects be not mistaken for that of the young larvæ.

(*b*) That the lac-bearing twigs required for propagation are cut before the crop is gathered, and that they be cut at such a period as to ensure that there is time to tie them on to the trees on which lac is to be propagated *before* the larvæ begin to issue. As far as the quality of the lac itself is concerned it would seem at present immaterial whether the crop is picked before or after the larvæ have swarmed.

3. Private Lands.

The above remarks apply equally to the improvement in the quantity and quality of the lac obtainable from private lands. It is more than probable that any improved methods of cultivation of, or increase in the production of, lac from Government district lands and reserved forests would be speedily followed by a similar improvement in the methods at present in force on private lands in British India.

4. Native States.

Mysore, Hyderabad, and the Central Indian States are amongst the chief Native States which cultivate lac, and foremost amongst them Rewah stands out pre-eminently with a revenue of upwards of four lakhs of rupees per annum from this source. This revenue is realized owing to the substance having been made a Government monopoly and its cultivation more or less enforced.

Both the cultivation and the collection of the article leave much to be desired, however, in the Native States of the country, complaints

from manufacturers being very rife as to the mutilated and dirty condition in which the material arrives at the factories.

In Rewah, the Butea frondosa is the chief lac tree and this has been placed on a footing similar to that of the Sandal in Mysore. In the neighbouring small State of Nagode, which is under British supervision, things are on a better basis. The cultivation in this State is done by voluntary workers in selected patches of *Butea frondosa*, no restrictions being imposed on the cutting of the tree in the fields. The revenue obtained on these lines is yearly increasing and the introduction of and cultivation of lac in other Native States upon these lines is recommended as a profitable industry.

CHAPTER XIV.

INDUSTRIAL USES OF LAC.

The best lac is obtained from the Schleichera trijuga. This is a light golden resin known in the trade as *nagali* and from it the most valuable orange shellac is made. The next best comes from the Butea frondosa and is known as *baisakhi* or *katki* according to the month (Baisakh or Katik) in which it is gathered. It is darker in colour than the *nagali* and the shellac is in consequence less clear and bright. These are almost the only varieties used by European farms. The native factories, most of which turn out a very inferior article, utilize the produce of almost every tree on which the lac-insect is found. The best *nagali* comes from Sambalpur and Raipur, in the Central Provinces, and from the neighbourhood of Hazaribagh and Palamau, in Bengal. The latter places also give the best *baisakhi* and *katki*, but these varieties are to be found in many parts of the country.

This monograph is not concerned with the various uses to which lac is put after it has left the manufacturers' hands. It has been mentioned that shellac has assumed a vastly increased importance in the world owing to the great demand which exists for it outside India in electrical work and in the manufacture of gramophone records. It is also extensively used as a varnish and polish for furniture and metal; as a stiffening material for hats and as an ingredient in lithographic ink and as sealing-wax.

In India lac enters very largely into the agricultural, commercial, artistic, manufacturing, and domestic operations of the people. Large

numbers of people find employment in the work connected with its propagation, cultivation, collection, and manufacture into the various forms required in commerce. In the village it is used either as a varnish or colour medium in the production of tables, bed posts, chairs, boxes, platters, etc., etc. The silver and copper smiths employ it in their trades, as do the manufacturers of shields, swords, etc., which are varnished over with lac. The material is employed in the manufacture of painted pottery in Bengal, Gonda, Lucknow, Oudh, Peshawar and the Punjab. It is used by jewellers and also in the manufacture of the various classes of bangles by the lower classes. Lastly, in the large class of toys of every description made in India lac is extensively used for colouration purposes, whilst marbles, pens, sealing-wax, ink bottles, imitation fruit, and flowers are entirely made of it.

The following appeared in a recent number of the *Indian Trade Journal* :—

" In consequence of the free alcohol law coming into force in the United States from the 1st instant, it is expected that larger quantities of shellac will be used in the manufacture of varnish, hats, etc., and a further appreciation in the price of this material may therefore be expected. Of the 13,000 tons of shellac, including button-lac, exported in 1905-06 from Calcutta, by far the most important source of shellac, 6,000 tons went direct to the United States. This represented a large increase, and it is interesting to learn that the increased demand for shellac in the United States is said to be due to the manufacture of talking-machine records. This large demand makes it doubly necessary that reckless gathering of the crop in India should be prevented."

CHAPTER XV.

QUANTITIES AND VALUES OF LAC AND LAC-DYE EXPORTED.

The Director-General of Commercial Intelligence has very kindly favoured me with the following tables exhibiting the quantities and values of lac and lac-dye, respectively, exported from each of the maritime provinces of British India from 1875-76 to 1905-06.

The first five columns show exports by sea to foreign countries. In the case of Burma a second column has been added, as he kindly points

out, to show the quantity and value of lac sent from Burma to Bengal by coasting vessels, as this is a considerable item. The total of the first five columns therefore shows the total quantity and value of the lac sent from India (including Burma) to foreign ports; while the last two columns 5 and 6 show the quantity and value of the lac sent out by sea from Burma to foreign and to Indian ports, respectively :—

Statement showing the quantities and values of lac exported by sea to foreign countries from each of the maritime provinces in British India in each year from 1875-76 *to* 1905-06.

	(1) BENGAL.		(2) BOMBAY.		(3) SIND.		(4) MADRAS.		(5) BURMA.		(6) BURMA (BY COASTING TRADE TO OTHER PROVINCE).	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Cwt.	R	Cwt.	R	Cwt.	R	Cwt.	R	Cwt.	R	Cwt.	R
1875-76 .	91,338	72,37,814	102	4,300	27	177	2	104	1,446	49,346	9,802	2,74,403
1876-77 .	109,504	49,84,189	49	3,165	...	15	3	180	105	3,659	8,955	1,51,390
1877-78 .	93,422	33,05,048	198	10,560	1	16	...	20	1,354	14,75[illegible]	4,506	68,050
1878-79 .	82,038	27,77,461	124	3,219	...	...	119	2,122	881	9,070	5,224	47,254
1879-80 .	56,239	34,71,750	59	2,658	507	5,113	[illegible]7	489	425	8,381	6,062	1,90,971
1880-81 .	80,811	56,30,560	42	2,607	958	10,465	33	1,886	244	7,483	11,104	2,82,648
1881-82 .	111,953	70,85,399	77	5,074	412	9,900	1	27	126	2,925	6,505	1,44,670
1882-83 .	133,815	69,15,221	368	13,563	...	...	59	1,330	645	13,938	3,595	72,515
1883-84 .	110,695	55,17,250	578	21,229	410	12,189	48	1,638	81	1,000	4,309	75,636
1884-85 .	141,877	60,71,798	216	6,142	463	13,120	22	1,653	...	...	1,460	24,621
1885-86 .	150,779	58,28,478	72	2,525	472	11,310	58	2,903	438	6,015	2,769	43,780
1886-87 .	147,111	51,49,641	189	4,212	910	29,406	32	1,309	60	933	2,955	40,524
1887-88 .	148,728	49,80,131	330	7,942	405	13,616	320	5,505	296	5,484	2,820	46,909
1888-89 .	102,686	39,82,477	165	4,018	593	14,690	33	1,559	...	...	3,[illegible]26	59,977
1889-90 .	89,597	48,65,760	337	7,439	87	1,900	217	10,029	...	..	2,102	48,874
1890-91 .	146,894	78,02,957	45	2,511	203	6,390	18	790	90	1,738	4,396	1,04,340
1891-92 .	135,786	74,44,465	120	4,176	1,300	45,615	289	12,787	186	5,201	5,758	1,55,875
1892-93 .	125,565	77,87,653	53	3,840	836	40,225	74	4,168	416	13,619	8,559	2,10,532
1893-94 .	121,414	95,21,007	20	1,329	1,489	80,840	...	...	4	129	11,584	3,30,877
1894-95 .	159,339	1,39,57,727	43	2,794	1,264	1,0 ,300	...	...	126	3,918	10,679	3,48,[illegible]01
1895-96 .	202,151	1,83,00,615	35	2,777	385	22,640	72	4,050	174	5,928	24,070	4,79,294
1896-97 .	204,072	1,38,55,770	234	13,187	1,762	1,13,465	242	11,580	152	4,616	9,122	2,35,568
1897-98 .	216,938	1,06,15,226	614	29,741	834	50,015	121	4,004	296	10,217	10,486	2,12,342
1898-99 .	178,722	85,59,511	224	9,635	1,364	63,380	962	35,360	844	46,058	8,232	1,52,850
1899-1900	235,865	1,12,51,516	360	16,625	1,708	76,870	124	6,180	393	15,406	8,731	1,63,069
1900-01 .	222,235	1,04,63,891	1,165	52,201	2,938	1,13,655	613	19,743	117	4,48[illegible]	10,278	1,79,940
1901-02 .	155,172	95,22,129	212	10,061	1,339	58,240	334	14,571	14	260	14,788	4,40,348
1902-03 .	235,079	1,82,33,836	41	3,738	2,601	2,04,7[illegible]5	1,228	63,198	64	2,325	20,[illegible]82	7,68,959
1903-04 .	231,229	2,68,99,442	89	12,638	2,818	2,36,075	1,424	89,215	60	16,000	29,691	15,12,922
1904-05 .	234,427	3,01,03,575	295	39,137	4,395	5,49,335	906	66,798	108	5,276	23,977	12,15,162
1905-06 .	271,101	3,14,82,409	219	19,454	2,012	2,12,466	976	81,029	127	5,803	26,545	13,38,827

Statement showing the quantities and values of lac-dye exported by sea to foreign countries from each of the maritime provinces in British India in each year from 1875-76 *to* 1905-06.

	(1) BENGAL.		(2) BOMBAY.		(3) SIND.		(4) MADRAS.		(5) BURMA.	
	Quantity	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Cwt	R	Cwt.	R	Cwt.	R	Cwt.	R	Cwt.	R
1875-76 . . .	10,596	2,62,869	...	...	...	..	...	...	72	2,854
1876-77 . . .	19,051	3,78,556	...	...	...	...	...	...	..	...
1877-78 . . .	9,569	2,90,074	...	...	1	13	...	...	...	...
1878-79 . . .	8,256	1,95,182	...	...	5	103	...	...	...	...
1879-80 . . .	13,609	2,24,271	...	...	181	2,297	...	...	...	...
1880-81 . . .	5,836	1,24,939	...	...	468	5,250	...	12	...	...
1881-82 . . .	4,252	75,612	...	...	780	16,346	...	...	...	...
1882-83 . . .	3,847	43,904	...	...	80	2,200	...	...	...	...
1883-84 . . .	997	14,085	...	...	...	...	...	...	...	...
1884-85 . . .	90	986	16	288	...	...	...	...	...	...
1885-86 . . .	911	13,600	...	...	873	18,030	...	...	...	...
1886-87 . . .	377	4,561	...	...	538	11,627	...	...	...	...
1887-88 . . .	279	6,205	...	...	...	...	...	...	...	...
1888-89 . . .	40	218	...	...	294	7,820	...	...	...	...
1889-90 . . .	1	5	...	...	328	8,672	...	...	...	...
1890-91 . . .	...	...	...	...	163	5,018	...	...	...	...
1891-92 . . .	..	...	...	...	45	2,500	...	...	...	...
1892-93 . . .	...	...	...	...	249	10,090	...	...	...	...
1893-94 . . .	...	...	...	...	90	4,600	...	...	...	...
1894-95 . . .	...	...	...	...	402	26,025	...	...	...	...
1895-96 . . .	15	1,705	...	...	...	...	...	...	...	...
1896-97 . . .	...	...	...	...	...	...	...	...	...	...
1897-98 . . .	...	36	...	...	...	...	...	...	...	...
1898-99 . . .		200	...	...	...	...	...	...	...	...
1899-1900 . . .	...	...	...	...	1	24	...	...	...	...
1900-01 . . .	1	14	...	..	...	...	...	...	...	...
1901-02 . . .	...	...	..	..	...	...	...	...	...	...
1902-03 . . .	...	...	...	...	...	...	...	...	...	..
1903-04 . . .	...	...	...	...	...	...	...	...	...	...
1904-05 . . .	...	...	...	...	...	...	...	...	...	...
1905-06 . . .	...	...	...	...	...	...	...	...	...	...

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APPENDIX I.

TIMBERS USED IN LAC TURNERY.

The use of lac on the large scale in India involves the utilization of a considerable amount of wood in the manufacture of the various articles for which the substance is so largely in demand. The following list of trees, the wood of which is used in lac turnery, was compiled by Dr. (now Sir George) Watt and is taken from his report on 'Lac and Lac Industries' published in the Agricultural Ledger No. 9 (1901).

Acacia arabica, Wild. (Leguminosæ), the *Kikar* or *babul*, Hoshiarpur, Shahpur, etc. In Jaipur it is specially mentioned as suitable for Indian clubs—Mugdars.

A. Catechu, Wild., the *Khair* of Hoshiarpur ; Jaipur mentions it as used for the feet of *charpoys* and *musals*.

A. modesta, Wall., the *Phulah* of Hoshiarpur.

Adina cordifolia, Hook. f. (Rubiaceæ), the *Haldu* of Saharanpur ; the *Aladran* of Surat, where it is said to be largely used for cradles (palnas), etc.

Ailanthus excelsa, Roxb. (Simarubeæ), used in Jaipur for scabbards, etc.

Albizzia Lebbek, Benth. (Leguminosæ), the *Shrin* of Shahpur.

Anogeissus latifolia, Wall. (Combretaceæ), the *Dhau* of Marwar.

Artocarpus Chaplasha, Roxb. (Urticaceæ), the *Sam* of Assam.

A. integrifolia, Linn. f., the jack-fruit tree, Assam.

Anthocephalus Cadamba, Miq. (Rubiaceæ), the *Kadan*, is in Alwar used for toys, bottles, jugs, etc.

Bauhinia latifolia (Leguminosæ), the Jinja of Marwar.

Bombax malabaricum, DC. (Malvaceæ), the *Semul* is in Alwar used for boxes, packing cases, toys, scabbards, fishing floats, linings of wells, etc.

Borassus flabillifer, Linn. (Palmæ), the *Tala* or *Arna*, according to Dr. Hendley is in Jaipur used to make painted animals. It is a soft and weak wood, but can be worked easily.

Boswellia thurifera, Roxb. (Burseraceæ), is the *Salai* wood of Jaipur, is specially used in making *hooka* pipes or *nechas*.

Cassia Fistula, Linn. (Leguminosæ), the *Sonaru* of Assam.

Cedrela Toona, Roxb. (Meliaceæ), the *Tun* of Saharanpur, Hoshiarpur, Dera Ghazi Khan, and Shahpur.

Cordia Myxa, Linn. (Boraginaceæ), is in Jaipur known as *Gondi* and it is said to be used for *hooka* shafts.

C. Rothii, R. and S., the *Gundi* of Marwar.

Dalbergia Sissoo, Roxb. (Leguminosæ), the *Shisham* of Saharanpur ; the *Tahli* of Hoshiarpur is mentioned in connection with Jaipur as good for opium boxes, charpoy legs, chilums and *sulphis* (datura-flower-shaped chilums). In Ulwar it is stated this wood is used for all sorts of furniture and turnery.

Eugenia Jambolana, Lam. (Myrtaceæ), *Jamun* wood, is in Jaipur mostly used for *naichas* or smoking pipes, *Chilum-ki-nalis* (tobacco-pipe stems).

Gmelina arborea, Linn. (Verbenaceæ), the *Kumber* or *Kunbher* of Ulwar. Is used for making *saringis* (musical instruments), cups, toys, furniture, pannels of carriage doors, and all kinds of ornamental work. It takes paint, polish, and lac readily.

Holarrhena antidysenterica, Wall. (Apocynaceæ), the *Kura* of Saharanpur; the *Veppalai* supposed to be used in Vellore, North Arcot, for lac turnery.

Jasminum grandiflorum, Linn. (Oleaceæ), the *Chameli* wood of Jaipur is good for toys, but too soft for charpoy legs.

Lagerstrœmia Flos-reginæ, Retz. (Lythraceæ), the *Ajur* of Assam.

Mangifera indica, Linn. (Anacardiaceæ), the mango, is largely used in Agra ; occasionally in Hoshiarpur ; is only rarely used in Jaipur.

Melia Azedarach, Linn. (Meliaceæ), the *Drek* of Hoshiarpur.

Mesua ferrea, Linn. (Guttiferæ), the *Nohar* of Assam.

Millingtonia hortensis, Linn. F. (Bignoniaceæ), the *Akas nim* of Saharanpur.

Mimusops indica, Kurz. (Sapotaceæ), the *Khirini* of Indergarh in Kohat State, Rajputana.

M. Kauki, Linn., is said to be the *Khirini* of Shahpura in Rajputana, where it is said to be imported from Jaipur and Gwalior.

Morus indica, Linn. (Urticaceæ), the *Shahtut* is in Jaipur used for making Dunkas and snuff boxes.

Olea cuspidata, Wall. (Oleaceæ), the *Kan* of Shahpur.

Pinus longifolia, Roxb. (Coniferæ), the *Chil* of Hoshiarpur.

Populus euphratica, Oliv. (Salicaceæ), the *Bhan* of Shahpur ; this is the *Bhan* of Hyderabad, Sind, where it is extensively used and much

appreciated for turnery owing to its taking colour easily ; it is a common tree in Sind, especially on river banks.

Psibium Guyava, Linn. (Myrtaceæ), the Guave is, according to a letter received from Mr. E. Thurston, used in Vellore, in North Arcot, for lac turnery.

Stephegyne parviflora, Korth. (Rubiaceæ), the *Kain* of Saharanpur.

Sterculia urens, Roxb. (Sterculiaceæ), the *Kadhu* of Ulwar. Sitars (guitars) and toys are made of it.

Tamarix orientalis, Forsk. (Tamaricaceæ), the *Farash* of Agra, the *Ekean* of Shahpur, *Pharwan* of Ferozepur ; the *Lye* of Hyderabad, Sind.

Tecoma undulata, G. Don. (Bignoniaceæ), the *Rohira* of Marwar or *Roira* of Jaipur, used for charpoy legs, tobacco boxes, etc. In Ulwar this is the *Rohera* and it is said to be useful for toys, agricultural implements, and furniture ; it takes a beautiful polish.

Tectona grandis, Linn. (Verbenaceæ), the Teak wood or *Saguan* of Marwar, rarely used but largely in Khandesh District of Bombay.

Ulmus integrifolia, Roxb. (Urticaceæ), the *Kanaja* of Marwar ; the *Chhilal* of Jaipur, largely used for the *chalpat,* rattle, the *phirkness,* top, and the *chakis* or humming tops.

Wrightia tinctoria, R. Br. (Apocynaceæ), the *Dudhi* of Saharanpur ; the *Khirini* or *Khirni* of Marwar, of Indergarh, of Tonk, of Udaipur, of Jaipur ; *Kherna Sirohi,* W. Rajputana ; *Anni* or *Dudi* of Dholpur.

Mr. T. H. Storey of Udaipur, Rajputana, who furnished a botanical specimen, says : " This tree abounds in milky juice. Its wood is used in preference to any other owing to its being easy to work and takes lac colours better than any other wood." There is thus no doubt whatever that the *Khirini* of Udaipur is Wrightia tomentosa.—In Ulwar this wood is spoken of as *Khirna,* it is used for toys and scabbards.

Zizyphus jujuba, Lamk. (Rhamnaceæ), the *Bar* of Hoshiarpur, Shahpur ; *Bordi Sirdhi* of W. Rajputana.

APPENDIX II.

DISTRICTS FROM WHICH THE PRINCIPAL FIRMS IN INDIA WHO MANUFACTURE SHELLAC IMPORT STICK-LAC.

Enquiries were addressed to the four principal firms on the subject as to where they procured their stick-lac from.

The following reply was courteously forwarded by Messrs. Jardine, Skinner & Co. of Calcutta :—

1. The following are the districts from which we import stick-lac :—

Raipur, Bilaspur (Central Provinces) ; Manbhum, Singbhum, Lohardagga, Hazaribagh, Santhal Parganas, Gya, Palamau (Bengal) ; Mirzapur (United Provinces) ; Jubbulpur, Hoshangabad (Central Provinces) ; Rewah Native States (Central India).

2. Annual outturn of shellac, 1905-06, was about 6,000 maunds = R 7,20,000

3. We manufacture first quality lac-dye selling at R6 per maund

G. I. C. P. O.—No. 74 R. & A.—22-1-1908.—700.—A. G. J.

PLATE I.

Fig. 1.—Magnified egg skins from which larvæ have escaped

1*a*.—♂ Young larva, side view enlarged.

1*b*.—Do. do., dorsal view enlarged.

1*e*.—Antenna of young larva enlarged.

Fig. 1*c*.—♀ Young larva, side view.

1*d*.— Do. do, dorsal view.

1*f*.—Antenna of young larva enlarged.

Fig. 2.—Larva of Enblemma amabalis enlarged.

2*a*.—Pupa of do.

2*b*.—Cocoon of do.

2*c*.—♂ Moth of do.

2*d*.—♀ Moth.

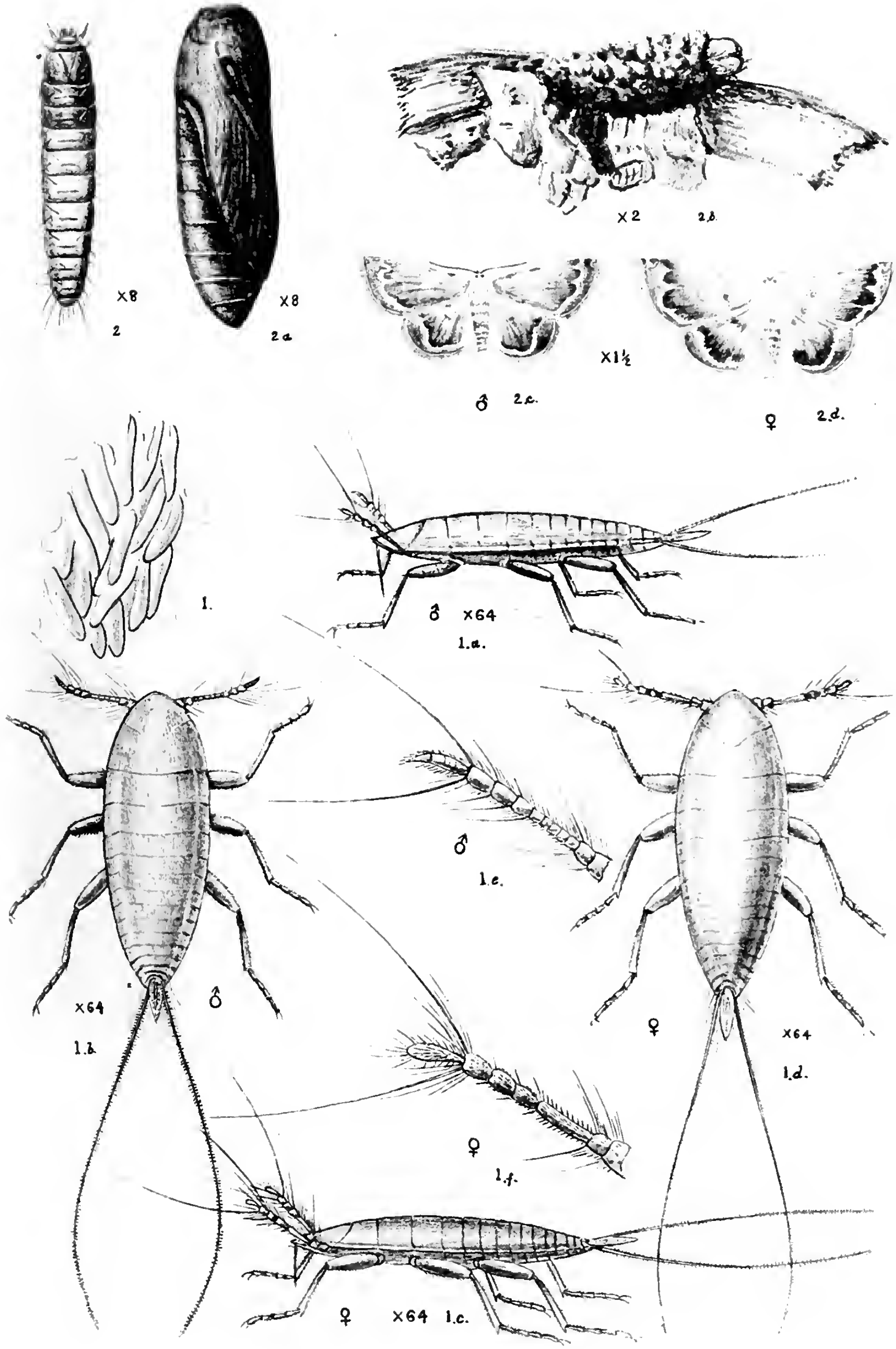

×8
2
×8
2a
×2
2.b.
×1½
♂ 2.c.
♀ 2.d.
1.
♂ ×64
1.a.
♂
1.e.
×64
1.b.
♂
♀
×64
1.d.
♀
1.f.
♀ ×64 1.c.

PLATE II.

Fig. 1.—Branch showing lac incrustation with swarming larvæ.

1*a*.—Same enlarged.

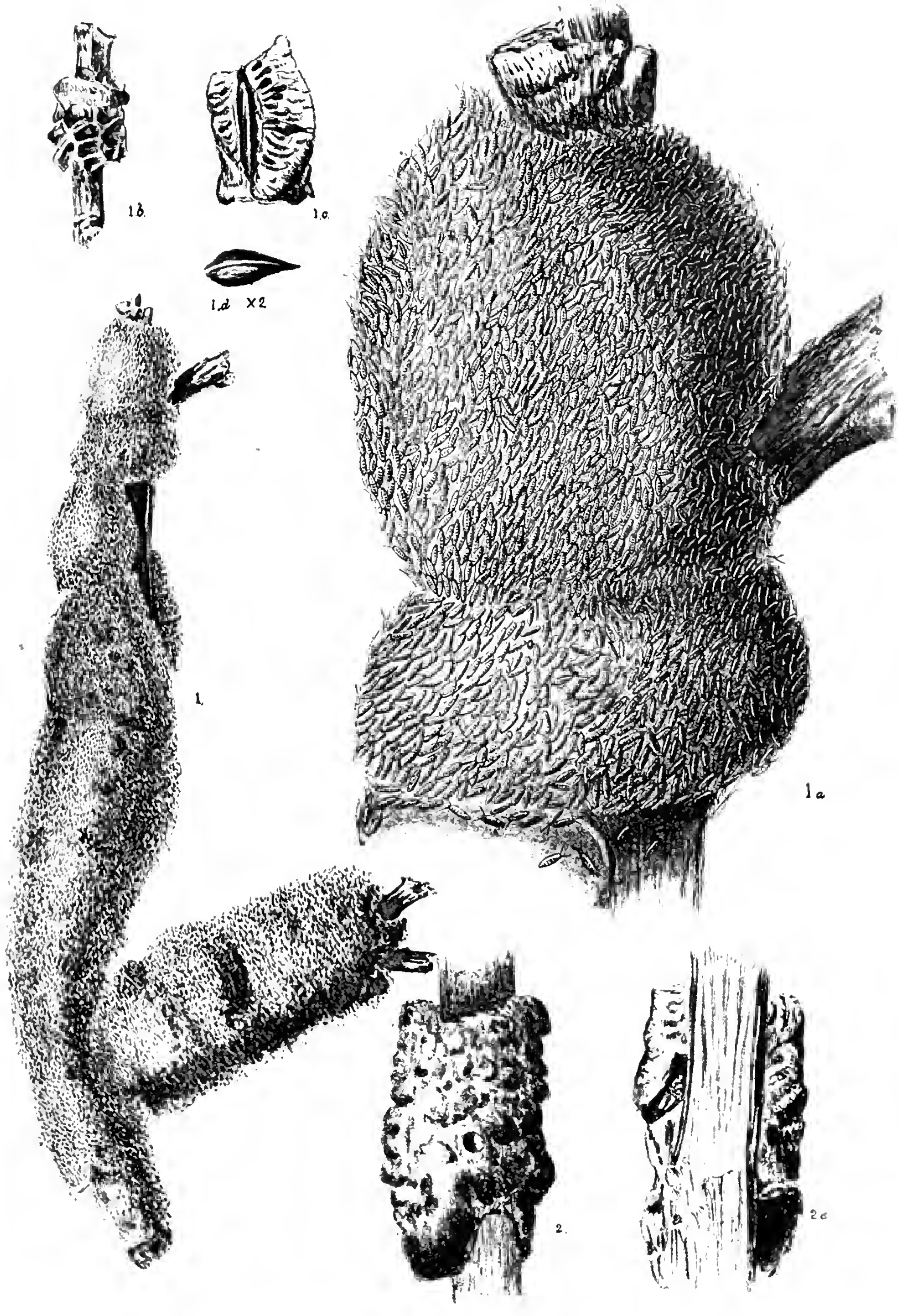
1*b*.—Transverse section of female cells to show structure.

1*c*.—Longitudinal section of same.

1*d*.—Empty skin of female taken from a cell.

Fig. 2.—Twig of lac showing holes made by the larva of Enblemma amabalis to enable moth to issue from interior of lac when the larva pupates.

2*a*.—Longitudinal section of a hole.


1 b.
1 c.
1 d ×2
1.
1 a
2.
2 a

VOL. I PART II

THE INDIAN FOREST RECORDS

A Preliminary Note on the Development of the Sal in Volume and in Money-Value

BY A. M. F. CACCIA, M.V.O., F.Z.S., I.F.S.,
Imperial Superintendent of Forest Working Plans

(With 1 Illustration and a Map)

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VOL. I, PART 1.—A Note on the L[illegible] ([illegible]), its [illegible] propagation and [illegible] Stebbing, F.L.S., F.Z.S., F.R.S.

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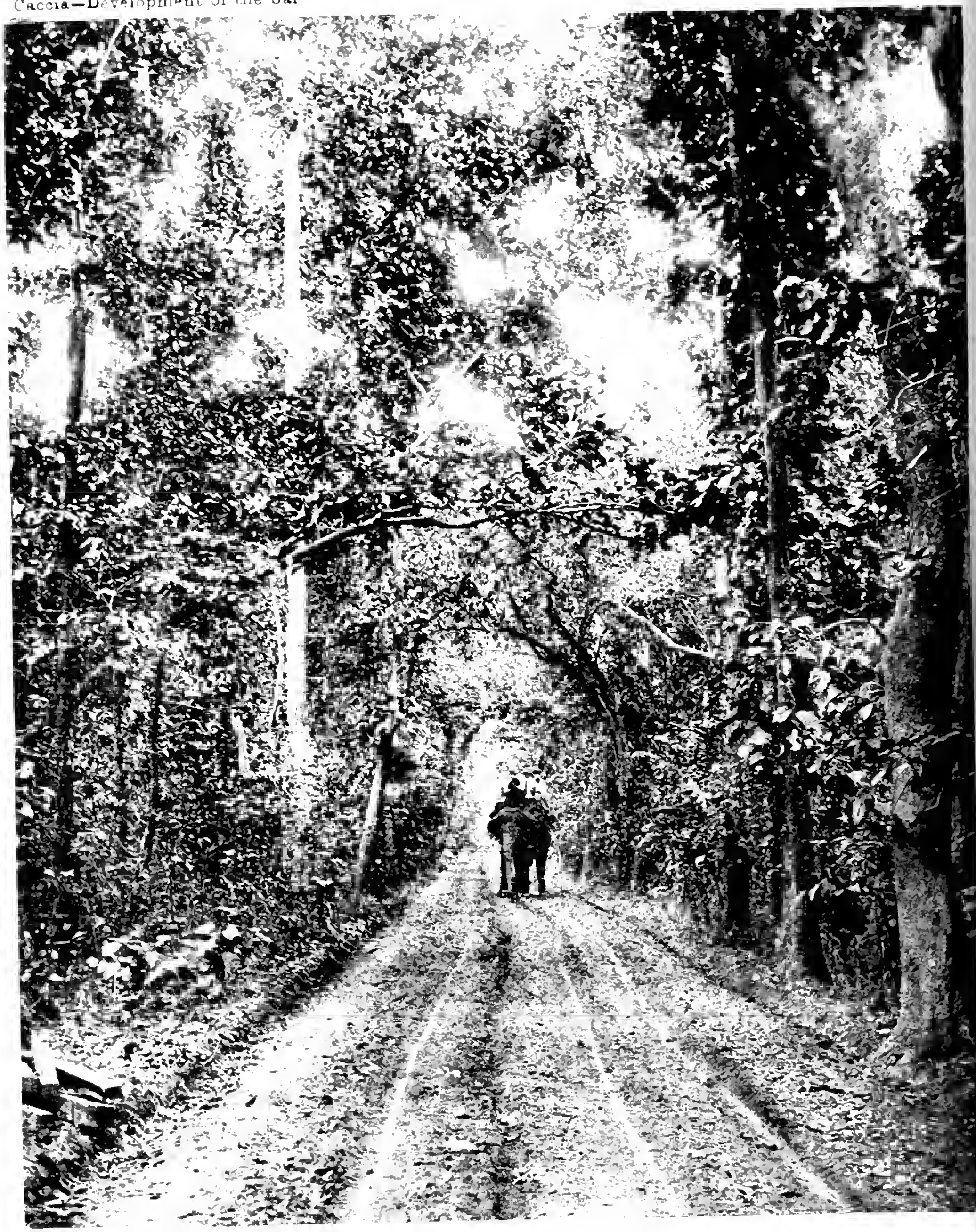

Fire Protected Sal Forest through which improvement Fellings have passed.
United Provinces.

THE INDIAN FOREST RECORDS.

Part II] 1908 [Vol. I.

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INTRODUCTION.

A CORRECT knowledge of the laws which govern the development of single trees and whole woods forms the foundation of Economic Forest Management. The statistical data upon which these laws are based enable the forester to fix the age at which woods should be exploited in order to yield the greatest return in produce or in money, or the highest interest on the money invested, and in addition they supply precise figures clearly indicating the manner in which certain sylvicultural operations should be carried out in order to obtain the best results.

In the following pages an endeavour has been made to bring together the statistical data at present available regarding the development of Sal trees and Sal woods in volume and in money value. How little is now known will be made only too apparent. The deficiency may be largely attributed to the enormous extent of Divisional charges, the paucity of trained forest officers, frequent changes and transfers, and more specially to the absence of even-age woods, and the utterly ruined and wholly abnormal condition of many of the Sal forests. But perhaps even greater stress must be laid on the fact that much valuable information bearing on this subject has undoubtedly been lost sight of, and is not at present available, owing to the absence in the past of any agency

or central bureau for collating and recording the same. This work will now be undertaken by the officers of the Imperial Forest Research Institute at Dehra Dun ; and it is hoped that all information bearing on the development of the Sal will be freely supplied to the Imperial Superintendent of Forest Working-Plans in order that a more complete Note on the growth of the Sal may be issued at an early date.

Statistical data, to be of any real practical utility, must be based on a sufficiently large number of observations. Increment or volume tables derived from insufficient measurements, from single trees or woods taken haphazard in different localities, can only be deceptive and misleading. The co-operation of all trained foresters, working in concert according to a pre-arranged plan, is therefore essential in order that the data collected may lead to the preparation of increment tables of real practical utility.* On this account it is desirable that the energies of the Department should be concentrated wholly in working out a few selected problems. The subjects which probably call for more immediate consideration may be classified as follow :—

1.—The Growth of Single Trees.

(*i*) *The mean annual girth increment.*—The average number of years required in different localities by the principal Sal trees of a crop to attain girths ranging from $1\frac{1}{2}$ to 7 feet.

(*ii*) *The preparation of volume tables.*—The girth increment of single Sal trees is dealt with in Section 3, Part I of this Note. Though a great deal has been done to solve this important problem, a great deal still remains to be done, not only in laying out additional experimental areas with the object of bringing a larger number of trees under observation in different localities, but also in carefully checking, scrutinising, and if necessary reconstituting existing sample plots.

The collection of data which will lead to the preparation of stem or timber volume tables calls for early attention. At this initial stage it is suggested that both the girth at breast height and the total height of the trees measured be recorded, so that the effect of height of tree may be given full weight in the preparation of volume tables. A question of even greater importance is that dealing with the object in view, namely,

---

*Von Baur's tables giving the height, diameter, volume, etc., of spruce of different ages are based on the measurement of 55,874 trees. Similar tables prepared by Schwappach for Scotch Pine result from the measurement of 17,059 trees.

whether it is proposed to collect data for the preparation of *stem volume tables*, or merely *timber* or *merchantable volume tables* ; for it is obvious that measurements should be taken on similar lines by every recording officer. The preparation of *stem volume tables*, combined with figures showing the ratio of *merchantable* to *total contents*, so that the volume of merchantable timber may be obtained by the use of ordinary stem volume tables, is a procedure that may commend itself.

The great progress which has been made on the continent of Europe during the past half century in the collection of forest statistical data, whereby it has been found possible to publish tables for each of the principal European species showing according to age the corresponding height, diameter, and volume, the form factor, the total volume. and the proportion between timber and branch wood and small wood, must primarily be attributed to the existence of a large number of centres or institutions specially engaged in working up such figures,* and to the resources placed at their disposal. But the success achieved in the collection of the data, upon which the published tables are based, is undoubtedly due to the holding of periodical Forest Conferences for the purpose of prescribing, after due discussion and consideration, a common programme of research work, subsequently enforced in all Forest Divisions. This procedure may well be copied in India. It is suggested to all Conservators that periodical (triennial or quinquennial) Provincial or Circle Conferences of forest officers be held, including representatives of the Imperial Forest Research Institute, with the object of elaborating a suitable programme of studies to be undertaken in each division under the direction of the Conservator during the ensuing period. It is felt that in this way alone can any real and continuous work of scientific investigation be devised and carried through.

Reference to the sylvicultural requirements of the Sal, except as regards the effects of "Thinnings" on the rate of growth, is necessarily omitted : but attention may be invited to Mr. Eardley-Wilmot's "*Notes on Sal forests : their life-history and treatment*," fully dealing with this subject.† The effects of fire-protection on the rate of growth, and particularly on natural reproduction in certain particular localities, also calls for special investigation.‡

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*There are nine Forest Research Bureaux in Germany alone.

†Calcutta, Office of Superintendent of Government Printing, India, 1898.

‡See Assam Annual Report for the year 1905-06, paragraph 3 of Resolution. Appendix A of this Note may also be consulted.

It has been thought useful to briefly indicate under each head the laws which have been found to govern the development of the volume and value of forest trees and crops in general.

In drawing up this Preliminary Note, Huffel's "*Les Arbres et les Peuplements Forestiers*," and Schlich's "*Manual of Forestry*" have been freely consulted, as well as other European authors referred to in the foot-notes.

Literature.

1. Notes on Sal Forests by S. Eardley-Wilmot.
2. A Manual of Indian Timbers, by J. S. Gamble, page 77.
3. A Concise Manual of Sylviculture, pages 53-56.
4. Indian Trees, by Dietrich Brandis, page 69.
5. Schlich's Manual of Forestry, Volume III, page 177.
6. Indian Forester, Volume IV, page 324 ; VI, 317 ; VIII, 188, 280 ; XI, 367 ; XII, 384 ; XV, 51, 109 ; XXIV, 445 ; XXV, 326 and Appendix ; XXVI, 32, 39, 389 ; XXVII, 583 ; XXVIII, 330, 411, 108, 179 ; XXIX 213 ; XXX, 393 ; XXXI, 376, 500, 147, 414.
7. Notes on the collection of data as to the growth of Sal trees and tree crops by means of sample plots, by F. A. Leete, F.C.H.
8. Working-Plans—

(*a*) Punjab—

(i) Working-Plan for the Kalesar forests, 1898.

(*b*) United Provinces of Agra and Oudh—

(i) Working-Plan for the Jaunsar Division, 1900.
(ii) Working-Plan for the Dehra Dun forests, 1903.
(iii) Working-Plan for the Saharanpur forests, 1883.
(iv) Working-Plan for the Ganges Forest Division, 1896.
(v) Working-Plan for the Lansdowne forests, 1904.
(vi) Working-Plan for the Garhwal Forest Division, 1893.
(vii) Working-Plan for the Rehar-Garibulchand forests, 1894.
(viii) Working-Plan for the Naini Tal Sub-Divisional forests, 1896.
(ix) Working-Plan for the Kumaun Forest Division, 1893.
(x) Working-Plan for the Pilibhit closed forests, 1894.
(xi) Working-Plan for the Pilibhit open forests, 1902.
(xii) Working-Plan for the Surai-Banbasa forests, 1901.
(xiii) Working-Plan for the Trans-Sarda forests, 1903.
(xiv) Working-Plan for the Bhira Range forests, 1894.

(xv) Working-Plan for the Hirapur Working Circle, 1896.
(xvi) Working-Plan for the Bhinga Range forests, 1893.
(xvii) Working-Plan for the Motipur Range forests, 1893.
(xviii) Working-Plan for the Chakia Charda forests, 1895.
(xix) Working-Plan for the Nawabganj forests, 1887.
(xx) Working-Plan for the Tulsipur forests, 1900.
(xxi) Working-Plan for the Gorakhpur forests, 1893.
(xxii) Working-Plan for the Berkala, Dholkhand and Ranipur Ranges, Sewalik Division, 1908.

(*c*) Eastern Bengal and Assam—
(i) Working-Plan for the Jalpaiguri reserved forests, 1904.
(ii) Working-Plan for the Buxa reserved forests, 1905.
(iii) Working-Plan for the Goalpara Sal forests, 1893.
(iv) Working-Plan for the Dambu forests, 1887.
(v) Working-Plan for the Darugiri forests, 1887.
(vi) Working-Plan for the Darrang Sal forests, 1906.

(*d*) Bengal—
(i) Working-Plans for the Tista Forest Division, 1896 and 1906.
(ii) Working-Plan for the Tista Valley forests, 1897.
(iii) Working-Plan for the Puri reserved forests, 1896.
(iv) Second Working-Plan for the Puri reserved forests, 1905.
(v) Working-Plan for the Singhbhum reserved forests, 1903.
(vi) Working-Plan for the Kurseong reserved forests, 1904.
(vii) Working-Plan for the Barapahar Range forests, 1898.

(*e*) Central Provinces—
(i) Working-Plan for the Jubbulpore Forest Division, 1899.
(ii) Working-Plan for the Banjar Valley forests, 1904.
(iii) Working-Plan for the Lormi Range forests, 1898.
(iv) Working-Plan for the Bawanthari Range forests, 1893.
(v) Working-Plan for the Balod Range forests, 1893.
(vi) Working-Plan for the Pertabgarh Range forests, 1897.
(vii) Working-Plan for the Sehawa Range forests, 1900.
(viii) Working-Plan for the Laun Range forests, 1898.
(ix) Working-Plan for the Chita Pandaria Range forests, 1895.
(x) Working-Plan for the Topla and Kuilikhapa Range forests, 1895.
(xi) Raigarh and Baihar ranges, 1907.

Part I.

DISTRIBUTION OF THE SAL.

PART I.

DISTRIBUTION OF THE SAL.

"THE Sal tree occupies two principal regions in British India. The first is a belt at the foot of the Himalaya and running into its valleys and up its lower hills to 3,000 or 4,000 feet, and exceptionally, as for instance at Lansdowne, to a still higher altitude." It is found "in the Kangra Valley and the regular continuous forest commences in the Ambala Siwaliks, west of the Jumna, whence it passes through Dehra Dun, Saharanpur, Bijnor, Kumaun, Oudh, Gorakhpur, Nepal, the Darjeeling Terai, Western and Eastern Duars, Kamrup, Garo Hills, Khasi and Jaintia Hills, Nowgong, with an outlier in the Darrang District. The second is the Central India belt, and the Sal country begins on the Ganges near Rajmehal and passes through the Sonthal Purganahs, Rewah, Chota Nagpur, the Central Provinces, Orissa, and the Northern Circars, ending in the Palkonda Range of Vizagapatam and the forests of Jeypur."*

From the tables which accompany this note it will be seen that in the area occupied by the Sal the mean annual rainfall varies from 40″ to 180″ and the elevation above mean sea level from 150 to 5,890 feet, thus indicating great adaptability on the part of this species so far as these two factors are concerned. As regards soil, however, the tree is far more exacting and a loose well-drained subsoil appears to be absolutely essential for its healthy development. The tree is almost exclusively confined to sandy or shingly soil and attains its best development when there is a fair admixture of humus with the upper layers. While the quality of the soil is thus chiefly responsible for the distribution of the tree within its area†, other factors, especially the amount of the annual

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*A Manual of Indian Timbers by J. S. Gamble, page 78.

† "The physical, and possibly the chemical, characteristics of the various rocks and soils appear to play an important part in the life history of the Sal, and the trap and laterite formations especially seem to affect its distribution and growth to an extent that makes their exact relative position of considerable interest and consequences." . . . "A detailed acquaintance with these forests (*Balaghat Division, Central Provinces*) is held to support the contention that soils derived from trap rocks, and to a lesser extent from mica quartz shist rocks, have a prejudicial effect on the growth of the Sal, so much so that where pure trap rock and soil occur the Sal is absent." *Working Plan for the Sal forests of the Balaghat Forest Division, Central Provinces,* **1906–1925,** *by A. Percival, I.F.S.*

rainfall and the elevation, also have a considerable effect on its rate of growth and the quality of its timber.

For statistical purposes it will be convenient to divide for the present the Sal-bearing regions of India into the following three tracts, each of which occupies a distinct geographical position, and which are characterised by marked differences in their annual rainfall. When further information becomes available regarding the factors which influence the growth of the Sal these statistical regions will probably have to be subdivided :—

I.—*The plains or Sub-Himalayan tract* of the United Provinces, including the Kangra and Simla Divisions of the Punjab; situated between latitudes 32° 47′ and 26° 42′ North, and longitudes 76° 10′ and 83° 40′ East; with a mean annual rainfall of 40 to 118 inches.

II.—*The East Himalaya tract* from Nepal eastwards, including Eastern Bengal and Assam and the Darjeeling, Tista, and Kurseong Divisions of Bengal Latitude 27° 11′ to 25° 36′ North; longitude 88° 22′ to 93° 10′ East; and mean annual rainfall 67 to 180 inches.

III.—*The Central India tract,* which includes the country lying south of the Jumna and north of the Godaveri River, the Central Provinces, the Sonthal Parganahs and Chota Nagpur. It falls within latitudes 25° 15′ and 19° 41′ North; longitudes 80° and 87° 50′ East; and has a mean rainfall varying between 46 and 67 inches per annum.

The following table gives the distribution of the Government Sal forest reserves within the three regions above defined* :—

*The Map at end of Note may also be consulted.

Name of Province.	Name of Conservator's Circle.	Name of Forest Division.	Name of Forest Reserve or Working Circle.	Area in acres.	Method of treatment.

I.—The Plains and Sub-Himalayan tract of the United

A.—THE PUN

Punjab.	Punjab.	Kangra Division.	Lohara B Reserved Forest Compt. I	486	Improvement fellings to obtain coppice shoots of Sal.
Punjab.	Punjab.	Kangra Division.	Lohara B Reserved Forest Compt. II	1,036	Improvement fellings to obtain coppice shoots of Sal.
Punjab.	Punjab.	Kangra Division.	Lohara B Reserved Forest Compt. III.	290	Improvement fellings to obtain coppice shoots of Sal.
Punjab.	Punjab.	Kangra Division.	Dhrui A Reserved Forest . . .	933	Improvement fellings to obtain coppice shoots of Sal.
Punjab.	Punjab.	Kangra Division.	Dhrui C Reserved Forest Compt. I.	84	Improvement fellings to obtain coppice shoots of Sal.
Punjab.	Punjab.	Kangra Division.	Dhrui E Reserved Forest.	8	Improvement fellings to obtain coppice shoots of Sal.
Punjab.	Punjab.	Kangra Division.	Andretta D Protected Forest.	180	Coppice with standards
Punjab.	Punjab.	Kangra Division.	Sal Reserved Forests .	3,017	.....
Punjab.	Punjab.	Simla Division.	Sal Valley Working Circle of Kalesar reserved forests . .	6,755	Improvement fellings .
Punjab.	Punjab.	Simla Division.	Sal Reserved Forests .	6,755	......
Punjab.	All Divisions.	All Divisions.	Sal Reserved Forests .	9,772	......

Latitude.	Longitude.	Elevation above Mean Sea Level in feet.	Mean annual Rainfall in inches.	REMARKS.

Provinces including the Simla Division of the Punjab.

IAB.

32° 47'	76° 10'	2,300'—2,900'	62"	
		2,200'—2,350'		
32° 46'	76° 15'	2,000'—3,000'		
		1,800'—2,200'		
32° 45'		2,200'—2,500'		
32° 2'	76° 37'	3,200'—4,000'	110"	
32° 47'—32° 2'	76° 10'—76° 37'	1,800—4,000'	62"—110"	
30° 27'—30° 19'	77° 33'—77° 38'	1,000'—2,000'	63·50"	Kalesar Working Plan, 1898—1922.
30° 27'—30° 19'	77° 33'—77° 38'	1,000'—2,000'	63·50"	
32° 47'—30° 19'	76° 10'—77° 38'	1,000'—1,400'	62"—100"	

B.—THE UNITED

Name of Province.	Name of Conservator's Circle.	Name of Forest Division.	Name of Forest Reserve or Working Circle.	Area in acres.	Method of treatment.
United Provinces.	Western Circle.	Jaunsar Division.	Kalsi Working Circle	249	Coppice with standards
			Sal Reserved Forests	249	...
		Sewalik Division.	Tirsal . .	14,783	Selection . . .
			Thano . .	4,883	Experimental . .
			Chandrabani . .	2,978	Coppice with standards
			Ramgar . . .	4,728	Ditto.
			Nawadah . . .	2,069	Ditto.
			Jamna . . .	34,428	Improvement . .
			Malhan . . .	22,795	Ditto .
			Ramgarh . .	20,926	Ditto . .
			Nagsidh . . .	12,077	Ditto .
			Ganges . . .	29,259	Ditto . .
			Sal Working Circle .	10,112	Ditto . .
			Coppice Working Circle.	25,522	Coppice with standards
			Sal Reserved Forests	184,560	...

Latitude.	Longitude.	Elevation above Mean Sea Level in feet.	Mean Annual Rainfall in inches.	REMARKS.
PROVINCES.				
30° 32′	77° 55′	1,800′—2,000′	80·99″	
30° 32′	77° 55′	1,800′—2,000′	80·99″	
30° 8′—30°	77° 40′ to 78° 20′	1,000′ to 3,000′	86″	Working-Plan of the Dehra Dun Forest Division, 1903—1927.
30° 10′				
30° 15′ to 30° 10′				
30° 15′—30° 10′				
30° 15′—30° 10′				
30° 10′—30° 2′				
30° 10′—30° 5′				
30° 2′—29° 55′				
30° 11′—30° 3′	77° 57′—78° 4′	1,750′—1,800′	50″	Revised Working-Plan for the Berkala, Dholkhand and Rampur Ranges, 1908—1937.
30° 17′—29° 56′	77° 44′—78° 10′	1,750′—1,800′		
30° 17′—29° 55′	77° 40′—78° 20′	1,000′—3,000′	50″—86″	

B.—The United

Name of Province.	Name of Conservator's Circle.	Name of Forest Division.	Name of Forest Reserve or Working Circle.	Area in acres.	Method of treatment.
United Provinces—*contd.*	Western Circle—*contd.*	Ganges Division.	Palain . . .	28,462	Selection . . .
			Gohri . . .	37,885	Improvement . .
			Udepur . . .	52,431	Ditto . .
			Kohtri . . .	45,175	Ditto . .
			Sona Nadi . .	59,791	Ditto . .
			Chandi . . .	32,931	Protection . . .
			Lansdowne Reserve .	11,440	Selection . . .
			Sal Reserved Forests .	268,115	...
		Garhwal Division.	Taria . . .	40,913	Selection . . .
			Ramganga . .	28,021	Improvement . .
			Dhikala . . .	30,835	Ditto . .
			Laldhang . . .	70,087	Protection . . .
			Chilkia . . .	39,248	Improvement . .
			Kotah . . .	50,577	Ditto . .
			Rehar-Garibulchand .	23,239	Ditto . .
			Kilauli . . .	7,875	Ditto . .
			Sal Reserved Forests .	290,795	...

Latitude.	Longitude.	Elevation above Mean Sea Level in feet.	Mean Annual Rainfall in inches.	REMARKS.
PROVINCES—*contd.*				
30° 0′ to 29°30′	78° 15′ to 78° 50′	1,000′—4,000′	45″—90″	Working-Plan of the Ganges Forest Division, excluding Lansdowne, 1896—1913.
...	...	2,000′—4,000′	60″—80″	Working-Plan for the Lansdowne Reserved Forests, 1904—1933.
30° 0′—29° 30′	78° 15′—78° 50′	1,000′—4,000′	45″—90″	...
29° 50′—29° 20′	78° 45′—79° 15′	1,100′—4,000′	66″—118″	Working-Plan of the Garhwal Forest Division, excluding Rehar-Garibulchand Forests, 1893—1912.
29° 20′	79°	750′—1,100′	40″—70″	Working-Plan for the Rehar-Garibulchand-Kilauli Forests, 1894—1915.
29° 50′—29° 20′	78° 45′—79° 15′	750′—4,000′	40″—118″	

B.—THE UNITED

Name of Province.	Name of Conservator's Circle.	Name of Forest Division.	Name of Forest Reserve or Working Circle.	Area in acres.	Method of treatment.
United Provinces—*contd.*	Western Circle.	Naini Tal Division.	Dolmar-Mora . .	1,586	Coppice with standards
			Mangoli . . .	970	Ditto.
			Sal Reserved Forests .	2,556	.. ...
	Eastern Circle.	Kumaun Division.	Kathgodam . .	30,775	Selection and Improvement.
			Hill Working Circle .	67,694	Protection only . .
			Jaulasal . . .	13,823	Improvement . .
			Sarkhet . . .	23,855	Selection . . .
			Nandhaur . . .	41,290	Selection and Improvement.
			Kalaunia . . .	37,558	Selection and Improvement.
			Sanani . . .	14,632	Improvement . .
			Horai-Lakhmanmandi	6,576	Ditto . . .
			Sal Reserved Forests .	236,203	......
		Pilibhit Division.	Closed Reserves or W. C. I.	45,123	Improvement . .
			Chukia . . .	11,400	Ditto . .

Latitude.	Longitude.	Elevation above Mean Sea Level in feet.	Mean Annual Rainfall in inches.	REMARKS.
PROVINCES—*contd.*				
29° 16′	79° 34′	2,000′ —4,500′	90″	Working-Plan for the Naini Tal Sub-Divisional Forests, 1896—1915.
29° 20′	79° 25′	2,200′ —4,000′		
29° 20′—29° 16′	79° 25′ —79° 34′	2,000′ —4,500′	90″	...
29° 30′—29°	79° 15′ —80° 20′	750′ —5,890′	From 76·67 at Haldwani to 95·33 at Naini Tal.	Working-Plan for the Kumaun Forest Division, 1893—1912.
29° 30′—29′	79° 15′ —80° 20′	750′ —5,890′	76·67″ —95·33″	...
28° 47′—28° 31′	79° 59′ —80° 20′	621′	50″	Working-Plan for the Pilibhit Forest Division, 1894—1908.
28° 57′—28° 45′	—80° 2′ —80° 7′	640′	55″	Working-Plan for the Surai Banbasa Forests, 1901—1910.

Name of Province.	Name of Conservator's Circle.	Name of Forest Division.	Name of Forest Reserve or Working Circle.	Area in acres.	Method of treatment.
					B.—THE UNITED
United Provinces—*contd.*	Eastern Circle—*contd.*	Pilibhit Division—*contd.*	Neoria . . .	24,749	Weedings . . .
			Saunia . . .	1,610	Selection . . .
			Dhamela . . .	8,865	Coppice with standards .
			Puranpur . . .	41,555	Ditto.
			Sal Reserved Forests .	133,302	......
		Kheri Division.	Kanjaria, West Sal .	48,032	Selection . . .
			Khairagarh, East Sal .	79,105	Ditto . . .
			Kishanpur . .	15,721	Improvement . .
			Marha . . .	29,648	Coppice with standards .
			Khamaria . .	2,681	Closed and Protected .
			Hirapur Sub-Working Circle III *a*.	11,478	Improvement . .
			Hirapur Sub-Working Circle III *b, c, d*.	23,395	Coppice with standards .
			Hirapur Sub-Working Circle III *e*.	12,674	Unregulated . .
			Sal Reserved Forests .	222,734	......

Latitude.	Longitude.	Elevation above Mean Sea Level in feet.	Mean Annual Rainfall in inches.	REMARKS.
PROVINCES—*contd*				
28° 54′ —28° 43′	79° 58′ —80° 4′	630′	55″	
28° 57′ —28° 55′	80° 4′ —80° 7′	...	55″	
28° 43′ —28° 34′	79° 56′ —80′	616′	50″	Working-Plan for the Pilibhit open Forests, 1902—1917.
28° 43′ —28° 28′	80°—80° 20′	598′	50″	
28° 57′—28° 28′	79°50′ —80°20′	598′—640′	50—55″	...
27° 41′ 15″ to 28° 22′ 30″	81° to 80° 30′	512′ to 602′	50″	Working-Plan for the Trans-Sarda Forests, 1903—1932.
				Working Plan for the Bhira Range Forests, 1894—1917.
28″ 30′—28° 4′ 52″	80° 37′ 30″ —80° 21′ 30″	480′ to 575′	45″	Supplement to the Bhira Range Forests Working Plan, 1896—1917.
28° 41′—28° 5′	80°21′—80°38′	480′—602′	45″—50	...

B.—The United

Name of Province.	Name of Conservator's Circle.	Name of Forest Division.	Name of Forest Reserve or Working Circle.	Area in acres.	Method of treatment.
United Provinces—*contd.*	Eastern Circle—*contd.*	Bahraich Division.	Nishangara . .	21,794	Improvement . .
			Murtiha . . .	11,757	Ditto . .
			Motipur . . .	14,590	Ditto . .
			Babay . . .	5,520	Protection . . .
			Sajauli . . .	56,685	Ditto . . .
			Gubbapur . .	10,880	Improvement . .
			Sonpathri . . .	3,200	Ditto . .
			Gulra . . .	9,314	Ditto . .
			Sohelwa . . .	17,350	Protection . . .
			Bhinga . . .	29,057	Ditto . . .
			Chakia . . .	15,093	Improvement . .
			Charda . . .	8,667	Coppice with standards and light improvement fellings.
			Sal Reserved Forests .	214,007	......

Latitude.	Longitude.	Elevation above Mean Sea Level in feet.	Mean Annual Rainfall in inches.	REMARKS.
PROVINCES—*contd.*				
28° 14′ 45″ —28° 11′	81° 10′ 30″ —81° 20′ 30″	...	41″	Working-Plan for the Motipur Range Forests, 1893—1907.
28° 13′ 15″ —28° 6′ 30″	81° 17′ 30″ —81° 21′ 30″			
28° 6′ 30″ —27° 45′ 0″	81° 20′ 30″ —81° 25′ 15″			
28° 24′ 22″ —88° 2′ 0″	81° 3′ 45″ —81° 17′ 30″			
28° 0′ 45″ —27° 54′ 45″	81° 20′ 30″ —81° 27′ 0″			
27° 55′ 30″ —27° 50′ 35″	81° 59′ 20″ —82° 9′ 10″	400′ to 3,000′	50″	Working-Plan for the Bhinga Range Forests, 1893—1907.
27° 52′ 45″ —27° 48′ 45″	82° 8′ 20″ —82° 12′ 20″			
27° 47′ 30″ —27° 42′ 30″	81° 57′ 10″ —82° 1′ 50″			
27° 54′ 45″ —27° 47′ 20″	81° 59′ 15″ —82° 15′ 0″			
27° 54′ 0″ —27° 40′ 0″	81° 51′ 15″ —82° 3′ 45″			
28° 8′ 45″ —28° 1′ 45″	81° 26′ 45″ —81° 35′ 30″	...	·44″	Working-Plan for the Chakia-Charda Forests, 1895—1904.
27° 59′ 45″ —27° 54′ 52″	81° 41′ 15″ —81° 44′ 20″			
28° 24′—27° 40′	81° 10′ —82° 15′	400′—3,000′	41″—50″	......

B—THE UNITED

Name of Province.	Name of Conservator's Circle.	Name of Forest Division.	Name of Forest Reserve or Working Circle.	Area in acres.	Method of treatment.
United Provinces—*contd.*	Eastern Circle—*contd.*	Gonda Division.	Tikri . . .	13,281	Coppice with standards.
			Bhambar . . .	15,888	Selection . . .
			Tulsipur . . .	15,796	Ditto . . .
			Balahwa . . .	12,660	Ditto . . .
			Grazing Circles . .	30,000	Unregulated. . .
			Sal Reserved Forests .	87,625	...
		Gorakhpur Division.	Working Circle, No I	5,912	Coppice with standards.
			Ditto „ II	20,035	Ditto . .
			Ditto „ III	13,627	Improvement . .
			Ditto „ IV	6,126	Mejhar . . .
			Ditto „ V	24,885	Improvement . .
			Ditto „ VI	1,644	Ditto . . .
			Sal Reserved Forests .	72,229	...
		All Divisions.	Sal Reserved Forests .	1,711,126	...
Total for Tract I .			Sal Reserved Forests .	1,720,898	...

Latitude.	Longitude.	Elevation above Mean Sea Level in feet.	Mean Annual Rainfall in inches.	REMARKS.
PROVINCES—*contd.*				
27° 2′ 15″ — 26° 58′ 0″	82° 21′ 30″ —82° 13′ 45″	550′	46·81″	Working-Plan for the Nawabganj Forests, 1887—1906.
27° 49′ to 27° 34′	82° 15′ to 82° 45′	2,500′	49″—68″	Working-Plan for the Tulsipur Forests, 1900—1919.
27° 49′—26° 58′	82° 15′—82° 45′	550′—2,500′	49″—68″	...
26° 48′ 11″ —26° 41′ 43″	83° 27′ 50″ —83° 31′ 38′	325′	53·5″	Working-Plan of the Gorakhpur Forests, 1893—1912.
27° 13′ 5″ — 26° 55′ 51″	83° 15′ 57″ —83° 33′ 27″	325′	53·5″	
27° 18′ 26″ —27° 7′ 17″	83° 26′ 50″ —83° 36′ 0″	325′	53·5″	
27° 16′ 38″ —27° 7′ 6″	83° 27′ —83° 32′	325′	53·5″	
27° 24′ 53″ —27° 14′ 18″	83° 32′ 15″ —83° 42′ 30″	325′	53·5″	
27° 19′ 43″ —27° 18′ 29″	83° 46′ 52″ —83° 48′ 30″	325′	53·5″	
27° 24′—26° 42′	83° 15′ —83° 49′	325′	53·5″	...
30° 32—26° 42′	77° 40′ —83° 49′	325′—5,890′	40″—118″	...
32° 47′—26° 42′	76° 10′ —83° 40′	325′—5,890′	40″—118″	

Name of Province.	Name of Conservator's Circle.	Name of Forest Division.	Name of Forest Reserve or Working Circle.	Area in acres.	Method of treatment.
					II.—The East
					A.—BEN
Bengal.	Bengal.	Darjeeling Division.	Tista Valley . .	12,260	Selection . . .
			Sal Reserved Forests .	2,260	......
		Tista Division.	Tista . . .	6,000	Selection . . .
			Chel . . .	4,000	Ditto . . .
			Sal Reserved Forests .	10,000	......
		Kurseong Division.	Sukna Terai Forests .	12,552	Selection . . .
			Sukna Hill Forests .	5,362	Selection . . .
			Sal Reserved Forests .	17,914	......
	All Divisions.		Sal Reserved Forests .	30,174	......

Latitude.	Longitude.	Elevation above Mean Sea Level in feet.	Mean Annual Rainfall in inches.	REMARKS.

Himalaya tract.

GAL.

27° 5′—26° 59′	88° 26′—88° 30′	620′—4,000′	175″	Working-Plan for the Tista Valley Range Forests, 1907-1917.
27° 5′—26° 59′	88° 26′—88° 30′	620′—4,000′	175″	
27° 11′—26° 55′ 27° 1′—26° 52′	88° 29′—88° 41′ 88° 32′—88° 45′	300′—2,000′	150″—180″	Working-Plan for the forests of the Tista Division, 1896-1905.
27° 11′—26° 52′	88° 29′—88° 45′	300′—2,000′	150″—180″	
26° 50′—26° 47′ 26° 48′—26° 46′	88° 22′—88° 25′ 88° 23′—88° 25′	532′—1,903′ 431′—532′	150″ 139″	Working-Plan for the Reserved Forests in the Kurseong Division, 1904-1918.
26° 50′—26° 46′	88° 22′—88° 25′	431′—1,903′	133″—162″	
27° 11′—26° 46′	88° 22′—88° 45′	200′—3,000′	139″—180″	

B.—Eastern Bengal

Name of Province.	Name of Conservator's Circle.	Name of Forest Division.	Name of Forest Reserve or Working Circle.	Area in acres.	Method of treatment.
Eastern Bengal and Assam.	Eastern Bengal and Assam.	Jalpaiguri Division.	Apalchand . .	16,062	Improvement . .
			Lower Tondu . .	18,061	Ditto . . .
			Muraghat . .	15,103	Ditto . . .
			Mixed Working Circles	64,380	Coppice with standards
			Sal Reserved Forests .	113,606	......
		Buxa Division.	Buxa . . .	115,408	Selection . . .
			Barojhar . . .	20,017	Ditto . . .
			Haldibari . . .	17,753	Ditto . . .
			Sal Reserved Forests .	153,178	......
		Goalpara Division.	Ripu . .	75,796	Selection . . .
			Chirang . . .	42,341	Ditto . .
			Guma . . .	12,124	Ditto . . .
			Sal Reserved Forests .	130,261	......
		Garo Hills Division.	Dambu . . .	4,364	Selection . . .
			Darugiri . . .	2,448	Ditto . . .
			Sal Reserved Forests .	6,812	......

Latitude.	Longitude.	Elevation above Mean Sea Level in feet.	Mean Annual Rainfall in inches.	REMARKS.
AND ASSAM.				
26° 49′—26° 40′	88° 39′—88° 46′	300′—400′	130·52″	Working-Plan (revised) for the forests of the Jalpaiguri Division, 1904—1918.
26° 49′—26° 45′	89° 49′—88° 55′		157·36″	
26° 48′—26° 40	89° 2′—89° 5′			
......	...			
26° 49′—26° 40′	88° 39′—89° 5′	300′—400′	130″—157″	
26° 48′—26° 33′	89° 29′—89° 43′	859′—4,222′	157″	Working-Plan for the Reserved forests in the Buxa Division, 1905—1919.
26° 52′—26° 33′	89° 21′—89° 28′	...		
26° 43′—26° 28′	89° 43′—89° 55′	...		
26° 52′—26° 28′	89° 21′—89° 55′	859′—4,222′	157″	
27°—26° 30′	...	296′—795′	153″	Working-Plan of the Goalpara Sal Forests (expired in 1903, revised 1904—1907).
	90°—91°	259′—1,158′		
	...	175′		
27°—26° 30′	90°—91°	175′—1,158′	153″	
25° 43′—25° 39′	90° 51′ 90° 54′	1,089′—1,800′	120″	Working-Plan of the Dambu Forest.
25° 38′—25° 36′	90° 46′—90° 49′	1,000′—1,550′	120″	Working-Plan of the Darugiri Forests, 1890—1904.
25° 43′—25° 36′	90° 46′—90° 54′	1,000′—1,500′	120″	

B.—EASTERN BENGAL

Name of Province.	Name of Conservator's Circle.	Name of Forest Division.	Name of Forest Reserve or Working Circle.	Area in acre.	Method of treatment.
Eastern Bengal and Assam—*contd.*	Eastern Bengal and Assam—*contd.*	Darrang Division.	Balipara . . .	56,224	Improvement fellings and thinnings.
			Garumari . .	205	
			Singri Hill . .	1,200	
			Sal Reserved Forests .	57,629	......
		Nowgong Division.	Kukrakata .	3,936	Improvement fellings and thinnings.
			Diju . . .	5,800	
			Suang . . .	6,612	
			Bamuni . . .	449	
			Rong Khong . .	6,643	
			Dobaka . . .	29,305	
			Sildharampur . .	4,191	
			Duar Jungthung .	8,047	
			Chilabar . . .	8,288	
			Sonaikhusi . .	13,104	
			Kolahat . . .	15,208	
			Sal Reserved Forests .	101,583	......
		Kamrup Division.	Rani Reserve . .	10,796	......
			Kawasing . . .	3,060	......
			Jarasal . .	1,783	......
			Mataikhar , .	3,870	......
			Kulsi . . .	4,544	......
			Milmillia . . .	4,851	......

atitude.	Longitude.	Elevation above Mean Sea Level in feet.	Mean Annual Rainfall in inches.	REMARKS.
AND ASSAM—*contd.*				
26° 55'—26° 40'	92° 30'—92° 50'	250'—1,000'	90"	
26° 55'—26° 40'	92° 30'—92° 50'	250'—1,000'	90"	
26° 30'—26°	92° 15'—93° 10'	250'—1,000'	77"	
26° 30'—26°	92° 15'—93° 10'	250'—1,000'	77"	
......	...	...	67·19" and 90·42"	
......	...	...		
......	...	...		
......	...	...		
......	...	...	83"	
......	...	...		

B.—EASTERN BENGAL

Name of Province.	Name of Conservator's Circle.	Name of Forest Division.	Name of Forest Reserve or Working Circle.	Area in acres.	Method of treatment.
Eastern Bengal and Assam—*contd.*	Eastern Bengal and Assam—*contd.*	Kamrup Division.	Chhaygaon . .	3,093	Improvement fellings.
			Pantan . . .	27,640	......
			Mayang . . .	5,451	......
			Barduar . . .	17,307	......
			Barjuli . . .	1,222	......
			Jaipur . . .	806	......
			Nampathar . .	626	......
			Boradobhe . .	1,074	......
			Gezang . . .	8,669	......
			Jharakhuri . .	2,107	......
			Mugakhal Reserve .	319	......
			Sursuria . . .	963	......
			Khurkhuri . .	142	......
			Garubaldha . .	246	......
			Taraibari . . .	789	......
			Ghoraputa . .	118	......
			Khatkhati . .	614	......
			Khuksisikrabura .	2,481	......
			Dumpara . . .	478	......
			Simla . . .	312	......
			Dudkhuri . . .	173	......
			Sal Reserved Forests .	103,534	......
		All Divisions	Sal Reserved Forests .	666,603	......
Total for Tract II .			Sal Reserved Forests .	696,777	......

Latitude.	Longitude.	Elevation above Mean Sea Level in feet.	Mean Annual Rainfall in inches.	REMARKS.

AND ASSAM—*contd.*

Latitude.	Longitude.	Elevation above Mean Sea Level in feet.	Mean Annual Rainfall in inches.	REMARKS.
......	...	...		
......	...	...	83″	
......	...	...		
......	...	...		
......	...	...		
......	...	...		
......	...	...		
26° 15′—25° 45′	91°—91° 45′	150′—1,575′		
......	...	...		
......	...	...		
......	...	...	68·91″	
......	...	...		
......	...	...		
......	...	...		
......	...	...		
......	...	...		
......	...	...		
......	...	...		
......	...	...		
......	...	...		
......	...	...		
26° 15′—25° 45′	91°—91° 45′	150′—1,575′	67·19″ —90·42″	
27°—25° 36′	88° 39′—93° 10	150′—4,222′	67—157	
27° 11′—25° 36′	88° 22′—93° 10′	150′—4,222′	67—180	

III.—The Central

A.—BEN

Name of Province.	Name of Conservator's Circle	Name of Forest Division.	Name of Forest Reserve or Working Circle.	Area in acres.	Method of treatment.
Bengal.	Bengal.	Sonthal Parganahs.	Old Reserves . .	2,432	Selection . . .
			Other Forests . .	184,482	Unregulated . .
			Sal Reserved Forests .	186,914	......
		Palamau Division.	Palamau Reserved Forests . . .	65,639	Selection . . .
			Hazaribagh Reserved Forests . . .	36,392	Unregulated . .
			Hazaribagh Protected Forests . . .	20,780	Ditto . .
			Sal Reserved Forests .	122,811	......
		Singhbhum Division.	Saitba . . .	21,198	Coppice . . .
			Santara . . .	77,579	Selection . . .
			Kolhan . . .	48,351	Ditto . . .
			Koina . .	52,424	Ditto . . .
			Samta . . .	113,662	Ditto . . .
			Porahat . . .	96,897	Ditto . . .
			Protected Forests .	136,903	Unregulated . .
			Sal Forests . .	547,014	......

Latitude.	Longitude.	Elevation above Mean Sea Level in feet.	Mean Annual Rainfall in inches.	REMARKS.

India Tract.

GAL.

25°15'—24°18'	87°22'—87°50'	500'—1,600'	53·40"	
...	...	...	...	
25°15'—24°18'	87°23'—87°50'	500'—1,600'	53·40"	
23°57'—23°28'	84°2'—84°28'	564'—3,098'	51·29"	
24°36'—24°29'	85°33'—85°43'	638'—1,854'		
24°29'—24°4'	85°19'—86°30'	1,300'—4,479'		
24°36'—23°28'	86°30'—84°2'	564'—4,479'	51·29"	
22°50'—22°2'	85°—85°20'	750'—3,000'	53·65"	Working-Plan for the Reserved Forests of Singhbhum, 1903—1918.
22°50'—22°2'	85°—85°20'	750'—3,000'	53·65"	

Name of Province.	Name of Conservator's Circle.	Name of Forest Division.	Name of Forest Reserve or Working Circle.	Area in acres.	Method of treatment.
Bengal.	Bengal.	Chaibassa Division.	Singhbhum Protected Forests . . .	98,560	......
			Manbhum Protected Forests . . .	9,123	...
			Sal Reserved Forests .	107,683	......
		Puri Division.	Chandka . . .	1,072	Forests under conversion to Coppice .
			Khurda . . .	606	
			Banpur . . .	11,608	Selection . . .
			Sal Reserved Forests .	13,286	......
		Angul Division.	Raigoda . . .	65,447	Selection . . .
			Tulka . . .		
			Tikerpara . .		
			Durgapur . . .		
			Sal Reserved Forests .	65,447	......
		Sambalpur Division.	Barapahar . .	44,606	......
			Sambalpur Range .	40,000	......
			Sal Reserved Forests .	84,606	......
	All Divisions.		Sal Reserved Forests	1,127,761	......

Latitude.	Longitude.	Elevation above Mean Sea Level in feet.	Mean Annual Rainfall in inches.	REMARKS.
22° 50′ – 22° 0′	85° 20′ – 86° 4′	1,505′—2,673′	...	
23° 9′—22° 48′	86° 6′—86° 43′	1,447′—2,220′	...	
23° 9′—22° 0′	85° 20′—86° 43′	1,447′—2,673′	...	
20° 26′—19° 41′	84° 59′—85° 56′	500′—3,000′	56·94″	Second Working-Plan for the Reserved Forests in the Puri Division, 1905—1912.
23° 26′—19° 41′	84° 59′—85° 56′	500′—3,000′	56·94″	
21° 10′ 55″—20° 32′ 5″	84° 18′ 10″—85° 42′ 45″	600′—1,700′	46·33″	
21° 11″—20° 32′	84° 18′—85° 43′	600′—1,700′	46·33″	
21° 45′—21° 11′	83° 15′—84° 0′	750′—1,412′	67·39″	
21° 48—21° 0′	84° 0′—84° 22′	436′—2,341′		
27° 48′—21° 0′	83° 25′—84° 22′	436′—2,341′	67·39″	Poor Forests.
25° 15′—19° 41′	83° 25′—87° 50′	300′—3,000′	46·3—67·4″	

B.—Central

Name of Province.	Name of Conservator's Circle.	Name of Forest Division.	Name of Forest Reserve or Working Circle.	Area in acres.	Method of treatment.
Central Provinces.	Northern Circle.	Jubbulpur Division.	Machmacha .	8,707	Improvement . .
			Khitoli . . .	9,367	Ditto . .
			Karela . . .	386	Ditto . .
			Seotri . . .	2,498	Ditto . .
			Sal Reserved Forests .	20,958	......
		Mandla Division.	Banjar Valley . .	18,672	Selection . . .
			Motinala . . .	33,342	Ditto . . .
			South Phen . .		
			North Phen . .		
			Sal Reserved Forests .	52,014	......
	Southern Circle.	Balaghat Division.	Baihar . . .	15,746	Selection . . .
			Raigarh . . .	35,621	Ditto . . .
			Sal Reserved Forests .	51,367	......
		Bilaspur Division.	Lormi . .	285,760	Improvement . .
			Sonakhan . . .	(Small area)	Unregulated .
			Sal Reserved Forests .	285,760	......

Latitude.	Longitude.	Elevation above Mean Sea Level in feet.	Mean Annual Rainfall in inches.	REMARKS.
PROVINCES.				
23° 52′ 30″—23° 40′	80° 45′—81°	1,200′—1,600′	53·5″	
23° 53′—23° 40′	80° 45′—81°	1,200′—1,600′	53·5″	Poor Forest; average height 60 feet. Maximum average girth, 5 feet.
22°	80°	1,800′—2,000′	55″	
22° 30′	81°	2,000′—3,016′	55″	
22° 30′—22°	80°—81′	1,800′—3,016′	55″	
22° 20′—22°	80° 30—81°	1,500′—2,793′ 2,170′—2,954′	60″	Working-Plan under preparation.
22° 20′—22°	80° 30′—81°	1,500′—2′,954′	60″	
22° 40′—220° 15′	81° 30—82°	900′—3,400′	48·85″	
21° 37′—21° 22′	82° 43′—82° 29′	800′—1,689′	...	
22° 20′—22°	82° 30′—82° 43′	800′—3,400′	48·85″	

B.—Central

Name of Province.	Name of Conservator's Circle.	Name of Forest Division.	Name of Forest Reserve or Working Circle.	Area in acres.	Method of treatment.
Central Provinces—*contd.*	Southern Circle—*contd.*	Raipur Division.	North Sihawa .	140,000	No fellings of Sal allowed.
			South Sihawa . .	150,000	
			Kantranala block .	15,000	
			Sal Reserved Forests .	305,000	......
	...	All Divisions.	Sal Reserved Forests .	715,099	......
Total for Tract III .			Sal Reserved Forests .	1,842,860	......
Total for Tract I .			Sal Reserved Forests .	1,720,898	......
Total for Tract II .			Sal Reserved Forests .	696,777	......
Total for Tract III .			Sal Reserved Forests .	1,842,860	......
Grand Total for Tracts I, II, and III			Sal Reserved Forests .	4,260,535	......

Latitude.	Longitude.	Elevation above Mean Sea Level in feet.	Mean Annual Rainfall in inches.	REMARKS.
PROVINCES—*continued.*				
22° 34′—20° 2′	81° 48′—82° 13′	1,200′—1,500′ 1,500′-2,000′	50″	Preliminary Working-Plan Reports for these two first Ranges have been sent up.
21° 25′—21° 18′	82° 30—82° 35′	1,100′—1,500′		
21° 25′—20° 2′	81° 48′—82° 35′	1,100′—2,000′	50″	
23° 53′—20° 2′	80°—82° 43′	800′—3,400′	48·8″—60″	
25° 15′—19° 41′	80°—87° 50′	300′—3,400′	46·3″—67·4″	
32° 47′—26° 42′	76° 10′—83° 40′	325′—5,890′	40″—118″	
27° 11′—25° 36′	88° 22′—93° 10′	150′—4,222′	67″—180″	
25° 15′—19° 41′	80°—87° 50′	300′—3,400′	46″—67″	
32° 47′—19° 41′	76° 10′—93° 10′	150′—5,890′	40″—180″	

The Government Sal Reserved Forests, under the management of the Forest Department in the Bengal Presidency thus form a series of fairly compact blocks, situated between North latitude 32° 47′ and 19° 41′, and East longitude 76° 10′ and 93° 10′. Within this vast tract of country these forests occupy a total area of 4,260,535 acres, or 6,657 square miles; and though many of them are in a ruined, abnormal condition, with large blanks, and unproductive areas, yet the Sal tree, in the forests in which it occurs, in a climate and on soil which suit it, "is always the prevailing tree, greater in number of individuals than all the rest put together", frequently forming pure forests.* The important rôle which this species plays in Indian forest management cannot therefore be overrated, and a correct knowledge of its rate of growth in different localities and under varying conditions is indispensable to the forester.

*"The most uniformly gregarious among the timber trees of India". *Gamble, A. Manual of Indian Timbers, page* 78.

PART II.

THE DEVELOPMENT OF THE STEM OF SINGLE SAL TREES.

PART II.

THE DEVELOPMENT OF THE STEM OF SINGLE SAL TREES.

SECTION 1—PRELIMINARY MATTERS.

A Sal tree consists of a crown, stem, and roots. The stem is from an economic point of view by far the most valuable and important part of the tree, and the study of the progress of its growth is of the greatest importance to the forester. In the case of trees possessing distinct annual rings, the development of the stem, its growth in height, diameter and volume, the determination of the form factor, and the rate per cent. of volume increment at different periods of the tree's life may be accurately and easily ascertained by means of a "Stem analysis". Unfortunately this is not usually possible in the case of the Sal; and the forester has to resort to the periodical measurement of selected trees in sample plots. On this account the collection of accurate statistical data becomes a laborious operation, requiring sustained attention—a fact which may to some extent explain the meagreness of the information at present available; the almost complete absence of Sal trees of known age adding to the difficulties experienced. It must be remembered, moreover, that statistics based on insufficient measurements are worthless for all practical purposes: the value of any table or figure being proportionate to the number of trees measured.

SECTION 2.—HEIGHT INCREMENT.

Laws which govern height growth of single trees in general:—

A.—*Seedlings—*

I. Height growth is very slow at first, and up to a certain age (fifth year or later).

II. After that age, height increment increases rapidly, and usually culminates on the tree attaining an age of 10 to 50 years (age not known for Sal).

III. After culmination height increment drops until it reaches a low level at which it remains constant.

IV. Height growth is directly proportional to soil and climate.

V. Trees grown in properly thinned woods develop greater height than those grown isolated or in over-crowded woods.

B.—Stool Shoots.—

I. Development of height growth is proportional to the age of the tree coppiced.

II. Height growth is very fast at the commencement, culminating at an early age, frequently in the first or second year.

III. Height growth ceases at a comparatively early age.

The systematic collection of statistical data relating to the progress of height growth of Sal has received little attention; and the few available data merely represent the measurement of a very limited number of trees in scattered localities. On that account such figures are inapplicable and of small practical utility. The determination of the age at which the mean annual and the current annual height increment culminates; and the determination of the development of the height for various qualities of locality are nevertheless of special interest to the forester. The absence of distinct annual rings in the Sal renders a stem analysis impossible,* and in addition the number of trees of known age to be found in any one locality is extremely small. Two courses, however, are open to the forester, namely, (*a*) the periodical height measurement of selected trees in sample plots, and (*b*) the determination for different localities of heights corresponding to given girths.

The few height growth measurements so far recorded relate solely to the maximum height attained by mature Sal trees (five to ten feet in girth), in different localities.

These figures would appear to indicate that three very distinct or broad quality classes may at once be established; and, in the absence of any statistical data relating to the height development of single stems, the following classification may be accepted as a purely temporary measure, namely:—

Class I, or Best Quality of Locality. Maximum height growth over 100 feet.

Class II, or Medium Quality of Locality. Maximum height growth 60 to 100 feet.

Class III, or Lowest Quality of Locality. Maximum height growth under 60 feet.

In the best Sal tracts of the Singhbhum and Buxa Divisions, in the Kurseong Terai and in the Banjar Valley of the Central Provinces, Sal

* It is possible that in some of the tracts of Eastern Bengal and Assam, the annual rings of Sal trees may be sufficiently distinct to permit of a stem analysis: but further investigation appears to be necessary.

trees are found to attain a maximum average height of 120 feet, and in the Tista Valley Reserve of the Darjeeling Division trees 161 feet in height have been measured.*

The Sal forests of the Dehra Dun and Naini Tal Divisions, with a mean maximum height growth of 70 feet fall into Class II: whilst the Tulsipur reserve of the Gonda Division, the poorer Sal tracts of the Singhbhum and Mandla Divisions are examples of Class III, with height maxima varying between 40 and 50 feet, falling as low as 30 feet in the case of the Paranpur closed reserve of the Pilibhit Division.

In the Puri Reserved forests, Bengal, measurements were taken of 50 trees in each diameter class by Mr. C. C. Hatt, I.F.S., with a view to arriving at a proximate idea of the average heights and girths of the Sal in the different diameter classes, with the following results:—

Diameter Classes.	Average Height.		Average Girth.
	Feet.	Inches.	
3″ to 6″	39	9	14″
6″ to 1′	61	3	28″
1′ to 1′ 6″	80	8	48″
1′ 6″ to 2′	83	0	62″
2′ and over	100	0	86″

The following diagram (Fig. No. 1), prepared from data collected by Mr. F. A. Leete, F.C.H., exhibits the progress of height growth of the average Sal tree in the Trans-Sarda forests of the Kheri Division, United Provinces.

* The following are the actual dimensions of one tree, measured in the valley of the Great Rangit:—

Total height	161 feet.
Height to first branch	86 „
Girth 4 feet from ground	10 feet 8 inches.

Paragraph 34, Working-Plan of the Tista Valley Range forests, by F. B. Manson, 1895.

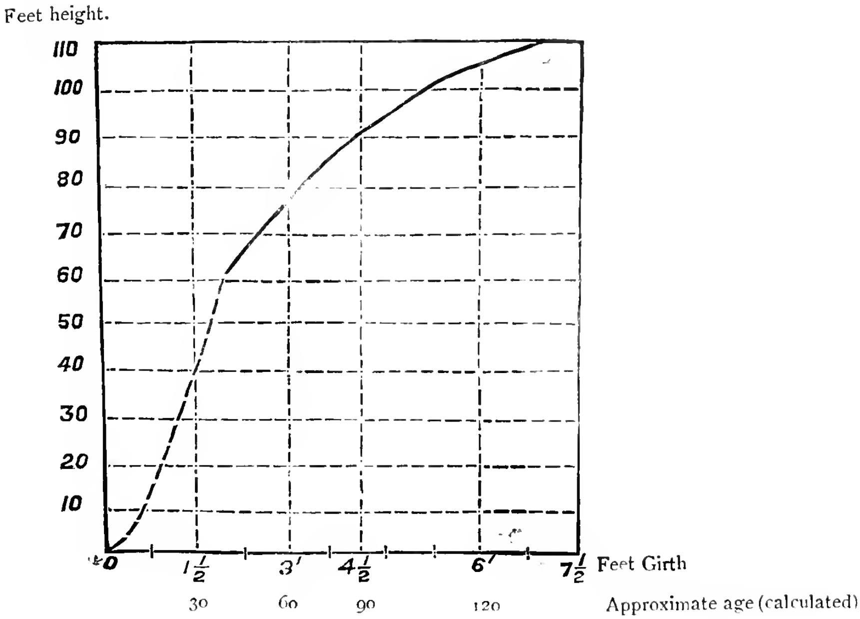

Fig. 1. Height growth of Sal in the Trans-Sarda forests, Kheri Division, United Provinces.

The collection of data relating to the height development of coppice shoots presents no difficulties. Sal forests, covering an area of 329,592 acres, are being systematically treated under the system of coppice with standards; and in these areas the height growth of selected coppice shoots of known age may be measured annually or periodically. It is hoped that this question will now receive attention. In the Singbhum Sal forests of Bengal coppice shoots attain an average height of 6 feet in the first year, whilst in the Mál forest of the Tista Division of Bengal coppice shoots are said to attain a height of 25 feet in two seasons with corresponding girth.

It remains to indicate the various problems relating to the height development of single Sal trees, which await solution:—

A.—*Seedlings*—

I. The development of height growth: the determination of the current annual (or periodic) and mean annual height increment of individual trees.

II. The determination of the age at which the current annual and mean annual height increment culminates.

III. The height corresponding to given diameters in different localities.

IV. The effect of thinnings (or growing space) on height development.

B.—*Coppice shoots*—

I. The total height of coppice shoots at different ages.

II. The current annual and mean annual height increment of individual coppice shoots.

III. The effect of the age (or size of diameter) of the tree coppiced on the height development of the resulting coppice shoots.

IV. The effect on the height growth of the thinning out of superfluous coppice shoots.

Section 3.—Girth Increment.

Laws which govern the girth development of single trees in general:—

I. In good soils, girth increment culminates at an early age, and subsequently diminishes fairly quickly.

II. In poor localities, girth increment is very slow, but remains constant for a long period.

III. In very crowded woods, the annual girth increment begins to diminish at an earlier date and continues to fall more quickly than in open woods.

The development of the girth of Sal trees has for some time received the attention of Indian foresters in connection with the preparation of Working-Plans, primarily for the purpose of ascertaining the age at which the principal trees of a Sal crop may be expected to attain girths varying from $5\frac{1}{2}$ to $7\frac{1}{2}$ feet. With this object in view, experimental plots have been established in several of the forest reserves under systematic management; and in these the girth of selected trees are annually or periodically measured. But a great deal still remains to be

done. It is essential that one or more sample plots should be laid out in each reserve under systematic working. Great care should be exercised in the selection of the type trees to be measured ; and the conditions under which these are growing should be clearly indicated.

The following table contains a list of all existing Sal sample plots, maintained by the Forest Department in the Bengal Presidency with the object of determining the rate of girth increment : the results of measurements so far recorded being also entered.*

*It must be confessed that many of the sample plots have not been well chosen : many of the selected trees now being measured have ceased to lay on a normal girth increment owing to accidents or to their complete suppression. The figures given are therefore open to revision. Moreover in only few instances have the trees grown up under protection, or under normal conditions of leaf canopy.

Name of Forest Division.	Name of Forest Reserve or Working Circle.	SAMPLE PLOT TO DETERMINE THE RATE			
		Name of Sample Plot.	Geological formation.	Soil and Sub-soil.	Latitude.
		I.—The Plains and Sub-Himalayan tracts of the United			
					A.— PUN
Kangra Division	Lohara B, Reserved.	......	..	...	...
	Forest, Compt. I	......	...	...	...
	„ „ II	......	...	...	...
	„ „ III	......	...	...	...
	Dhrui A, Reserved Forest.	......	...	...	...
	Dhrui C, Reserved Forest Compt I.	......	...	...	...
	Dhrui E, Reserved Forest.	......	...	...	...
	Andretta D, Protected Forest.	......	...	...	.
	Average for Division	......	...	...	.
Simla Division	Sal Valley Working Circle, Kalesar Reserved Forest.	Sample Plot No. I .	...	Contains large quantities of pebbles but is a fertile loam fairly moist and usually well covered with humus.	30°26'
	..	Sample Plot No. II .	...	Contains a quantity of pebbles : is loamy, fresh and fertile on the whole.	30° 26'
	Average for Division	......	...	...	...

OF GIRTH GROWTH OF SAL.					MEAN ANNUAL GIRTH INCREMENT.						
					Girth Class.						
Elevation above Mean Sea Level in feet.	Aspect.	Slope.	Mean Annual Rainfall in inches.	Number of Stems.	½′—1½′	1½′—3′	3′—4½′	4½′—6′	6′—8′	All classes up to 8′.	REMARKS.

Provinces including Simla Division, Punjab.

JAB.

...	...	..	...	...	...	...	...	...	...	...	No sample plots.
...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	..	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	..	...	...	...	...	...	...	
...	...	..	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	
1,700	...	...	63·50	...	0·77	0·59	0·48	...	...	0·61	
1,700	...	...	63·50	...	0·89	0·83	0·81	...	...	0·84	
...	...	...	...	...	0·83	0·71	0·64	...	...	0·72	

Name of Forest Division.	Name of Forest Reserve or Working Circle.	SAMPLE PLOT TO DETERMINE THE RATE			
		Name of Sample Plot.	Geological formation.	Soil and Sub-soil.	Latitude.
B.—UNITED PROVINCES OF					
Jaunsur Division.	Kalsi . .	......	...	...	...
	Average for Division.	......	...	......	...
Sewalik Division (Dehra Dun).	Tirsal . .	Tirsal . .	...	Clayey loam	30° 8′
	Thano . .	Thano . . .	...	Loam and bagri.	30° 13′
	Chandrabani .	......	...	......	...
	Ramgarh .	Ramgarh . . .	...	Clayey loam	30° 12′
	Nawadah .	......	...	......	...
	Jamna . .	Timli . . .	...	Sandy loam .	30° 13′
	Malhan . .	Malhan . . .	...	" "	30° 9′
	Ramgarh .	......	...	......	...
	Nagsidh . .	Nagsidh . . .	...	Clayey loam	30° 14′
	Ganges . .	Kansrao . . .	...	Red loam .	30° 5′
	Average for Division.	......	...	......	...
Sewalik Division, (Saharanpur).	Sal Working Circle.	Dholkhand No. I .	...	Sandy loam .	30° 6′
	Sal Working Circle.	" " II .	...	" " .	30° 6′
	Sal Working Circle.	Laharkote " I .	...	Sandy loam with humus.	30° 7′
	Sal Working Circle.	" " II .	...	Sandy loam with humus.	30° 7′
	Sal Working Circle.	Malowwala . .	...	Sandy loam	35° 5′

OF GIRTH GROWTH OF SAL.					MEAN ANNUAL GIRTH INCREMENT.						
					Girth Class.						REMARKS.
Elevation above Mean Sea Level in feet.	Aspect.	Slope.	Mean Annual Rainfall in inches.	Number of Stems.	½′—1½′	1½′—3′	3′—4½′	4½′—6′	6′—8′	A classes up to 6′.	
AGRA AND OUDH.											
...	...	...	...	..	...	...	...	...	...	...	No sample plot.
...	...	...	...	...	...	...	...	...	...	...	
1,500	...	...	101·98	...	0·48	0·59	0·73	...	...	0·52	
1,800	...	...	82·74	...	0·26	0·41	0·40	0·69	0·28	0·36	
...	...	...	...	...	...	...	...	...	...	...	No sample plot.
1,600	...	...	74·58	...	0·25	0·34	0·44	0·48	...	0·35	
...	...	...	...	...	...	...	...	...	...	...	No sample plot.
1,600	...	...	77·20	...	0·70	0·53	0·44	0·37	...	0·54	
1,800	...	...	74·14	...	0·44	0·37	0·44	0·51	0·24	0·40	
...	...	.	...	...	...	...	...	...	...	...	No sample plot.
1,900	...	...	82·74	...	0·54	0·68	0·61	0·39	...	0·61	
1,350	...	...	66·56	...	0·34	0·51	0·57	...	...	0·30	
...	...	...	...	...	0·41	0·46	0·45	0·51	0·26	0·45	
1,800	...	...	55·9′	...	0·47		...	...	...	...	Unthinned.
1,800	...	...	55·9′	...	0·69		...	...	...	...	Thinned.
1,750	...	...	55·9′	...	0·44		...	...	...	...	Unthinned.
1,750	...	...	55·9′	...	0·79		...	...	...	...	Thinned.
1,800	...	...	55·9′	...	...		...	...	...	...	

Name of Forest Division.	Name of Forest Reserve or Working Circle.	Sample Plot to determine the rate			
		Name of Sample Plot.	Geological formation.	Soil and Sub-soil.	Latitude.
Sewalik Division, (Saharanpur).—*contd.*	Coppice Working Circle.	...	...	..	...
		...	...	...	...
	Average for Division.	...	...	...	...
		...	...	...	...
Ganges Division.	Palain . .	...	...	...	...
	Gohri . .	Andermaghera . .	...	Upper soil coloured with humus over deep light loam going over 5′ down. Quality I.	... ...
	„ . .	Jogichaur . . .	...	Sandy loam mixed with boulder and gravel. Quality II.	... ...
	„ . .	Kauria . . .	...	Light loam on deep gravel mixed loam. Quality II.	... ...
	Udepur . .	Gewain	...	Boulder and gravel mixed with sandy loam. Quality II.	... ...
	Kohtri . .	Chaukhamb . .	...	Upper 6′ coloured by humus on deep light loam mixed with little gravel. Quality I.	... ...

F GIRTH GROWTH OF SAL.					MEAN ANNUAL GIRTH INCREMENT.						REMARKS.
					Girth Class.						
Elevation above Mean Sea Level in feet.	Aspect.	Slope.	Mean Annual Rainfall in inches.	Number of Stems.	½'—1½'	1½'—3'	3'—4½'	4½'—6'	6'—8'	All classes up to 6'.	
...	...	...	...	...	...	...	...	...	...	...	No sample plot.
...	...	...	...	...	0·72	...	...	...	...	...	Thinned.
...	...	...	...	...	0·46	...	...	...	...	...	Unthinned.
...	...	...	...	...	0·53	...	...	...	...	...	Thinned and unthinned.
...	...	...	...	...	...	...	...	...	...	...	No sample plot.
1,227	...	...	...	...	0·24	0·45	0·59	0·84	0·40	0·50	Thinned.
1,227	...	...	...	...	0·14	0·48	0·43	0·67	...	0·43	Unthinned.
1,095	...	...	...	...	0·34	0·48	0·55	0·63	...	0·50	Thinned.
1,095	...	...	...	...	0·60	0·71	0·77	0·81	...	0·72	Unthinned.
1,374	...	...	...	...	...	0·38	0·49	0·42	0·31	0·40	Thinned.
1,374	...	...	...	...	0·28	0·39	0·49	0·36	...	0·38	Unthinned.
2,200	...	...	...	...	...	0·47	0·55	0·97	...	0·66	Thinned.
2,200	...	...	...	...	...	0·24	0·27	...	...	0·25	Unthinned.
1,750	...	...	...	...	0·36	0·54	0·59	0·62	0·49	0·52	Thinned.
1,750	...	...	...	...	0·18	0·39	0·42	0·37	0·43	0·36	Unthinned.

Name of Forest Division.	Name of Forest Reserve or Working Circle.	SAMPLE PLOT TO DETERMINE THE RATE			
		Name of Sample Plot.	Geological formation.	Soil and Sub-soil.	Latitude.
Ganges Division.	Sona Nadi .	...	...	...	...
	Chandi . .	...	...	...	...
	Lansdowne .	Barswar . . .	...	Sandy loam mixed with gravel. Quality III.	... ...
	,, .	Bhankot . . .	...	Sandy loam mixed with gravel.	...
		...	...	...	...
	Average for Division.	...	...	...	...
		...	...	...	...
Garhwal Division.	Taria . .	Mandal I .	...	Red ferruginous sandy clay and clayey but bouldery underneath.	29° 38′
	,, . .	,, II . .	...		29° 38′
	Ramganga	Domanda I .	...	Sandy loam with boulders underneath.	29° 36′
	,,	,, II	...		29° 36′
	Dhikala .	S. Patli Dun I .	...	Sandy loam with boulders underneath.	29° 34′
	,, .	,, ,, II	...		29° 34′
	Laldhang .	...	...	...	...
	Chilkia	Amtanola I .	...	Sandy loam with boulders underneath.	29° 35′
	,,	,, II .	...		29° 35′

of Girth growth of Sal.					Mean annual Girth increment.						
					Girth Class.						
Elevation above Mean Sea Level in feet.	Aspect.	Slope.	Mean Annual Rainfall in inches.	Number of Stems.	½′–1½′	1½′–3′	3′–4½′	4½′–6′	6′–8′	All classes up to 6′.	REMARKS.
...		...	...	...	...	...	...	...	...	...	No sample plots.
...		...	...	...	...	...	...	...	...	..	
3,000		...	...	...	0 22	0·26	0·18	0·53	...	0·30	Thinned.
3,000		...	...	...	...	0·25	0·26	0·28	0·19	0·24	Unthinned.
3,059		...	...	...	...	...	...	...	...	...	Thinned.
3,050		...	...	...	...	...	...	...	...	...	Unthinned.
...	...	...	...	...	0·33	0·44	0·51	0·63	0·26	0·46	Thinned.
...	...	...	...	...	0·38	0·33	0·39	0·52	0·27	0·35	Unthinned.
...	...	...	...	...	0·36	0·39	0·47	0·58	0·35	0·41	Thinned and Unthinned combined.
3,000	...	...	60 to 118	...	0·59	0·75	0·65	0·61	0·47	0·67	Thinned.
3,000	...	...	60 to 118	...	0·24	0·37	0·32	0·33	0·50	0·35	Unthinned.
1,420	...	...	60 to 118	...	0·37	0·57	0·63	0·84	0.61	0·62	Thinned.
1,420	...	...	60 to 118	...	0·25	0·36	0·47	...	...	0·33	Unthinned.
1,300	...	...	60 to 118	...	0·55	0·84	0·96	...	...	0·84	Thinned.
1,300	...	...	60 to 118	...	0·33	0·63	0·91	0·76	0·40	0·47	Unthinned.
...	...	...	...	...	..	...	.	...	..	...	No sample plot.
1,800	...	...	60 to 118	...	...	0·64	0·56	0·65	0·87	0·61	Thinned.
1,800	...	...	60 to 113	...	...	0·26	0·42	0·47	0·62	0·35	Unthinned.

Name of Forest Division.	Name of Forest Reserve or Working Circle.	Sample Plot to determine the rate			
		Name of Sample Plot.	Geological formation.	Soil and Sub-soil.	Latitude.
Garhwal Division.	Kotah	...	...	...	...
	Rehar-Garibul-chand.	Rehar I	...	Sandy elay	29° 23′
	Rehar-Garibul-chand.	„ II	...		29° 23′
	Kalauli	...	...	...	...
	Average for Division.	...	...	...	...
		...	...	...	...
		...	...	...	...
Naini Tal Division.	Dolmar-Mora	...	...	...	...
	Mangoli	...	...	...	...
	Average for Division.	...	...	...	...
Kumaon Division.	Kathgodam	Mona Block I	...	Clayey loam	29° 15′
	„	Mona Block II compt. 3	...	„ „	29° 15′
	„	Mona Block III compt. 4.	...	„ „	29° 15′
	„	Mona Block IV compt. 5.	...	Loam	29° 15′
	„	Mona Block V compt. 6.	...	Sandy loam	29° 15′
	Hill Working Circle.	Sanman Thapla	...	Clayey loam	29° 10′
	Hill Working Circle.	„ „	...	„ „	29° 10′

of Girth growth of Sal.					Mean annual Girth increment.						Remarks.
					Girth Class.						
Elevation above Mean Sea Level in feet.	Aspect.	Slope.	Mean Annual Rainfall in inches.	Number of Stems.	½′—1½′	1½′—3′	3′—4½′	4½′—6′	6′—8′	All classes up to 6′.	
...	...	...	...	...	...	...	...	...	...	...	No sample plot.
1,000	...	...	60 to 118	...	0·28	0·51	0·58	0·83	...	0·57	Thinned.
1,000	...	...	60 to 118	...	0·19	0·37	0·45	0·48	...	0·58	Unthinned.
...	...	...	...	...	...	...	...	...	...	...	No sample plot.
...	...	...	...	...	0·34	0·57	0·60	0·63	0·52	0·55	Thinned and Unthinned.
...	...	...	...	...	0·49	0·69	0·66	0·69	0·56	0·66	Thinned.
...	...	...	...	...	0·29	0·40	0·40	0·41	0·48	0·38	Unthinned.
...	...	...	...	...	...	...	...	...	...	...	No sample plots.
...	...	...	...	...	...	...	..	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	
3,000	...	...	75 to 86	...	0·4	0·6	0·5	0·6	0·5	0·5	Unthinned.
3,000	...	...	75 to 86	...	0·5	0·6	0·3	0·4	0·2	0·4	Thinned.
3,000	...	...	75 to 86	...	0·1	0·2	0·3	0·2	0·3	0·2	Unthinned.
2,700	...	...	75 to 86	...	0·3	0·4	0·5	0·5	...	0·4	Thinned.
2,500	...	...	75 to 86	...	0·1	0·2	0·3	0·4	0·5	0·3	Unthinned.
1,200	...	...	75 to 86	...	0·1	0·2	0·3	0·3	0·7	0·3	”
1,200	...	...	75 to 86	...	0·4	0·4	0·4	0·5	0·7	0·5	Thinned.

Name of Forest Division.	Name of Forest Reserve or Working Circle.	Sample Plot to determine the rate			
		Name of Sample Plot.	Geological formation.	Soil and Sub-soil.	Latitude.
Kumaun Division.—*contd.*	Jaulasal . .	......	...	... ..	...
	Sarkhet . .	......	...	......	...
	Nandhaur .	Chila compt. 2 . .	...	Sandy loam .	29° 10′
	,, . .	Khonani North . .	...	,, ,, .	29° 10′
	,, . .	Selani . .	..	Clayey loam .	26° 10′
	,, . .	Aonlakhera South compt. 5.	...	Sandy loam .	29° 10′
	Kaulaunia .	. ...	...	......	...
	Sanani . .	......	. .	... ..	...
	Lakhmanmandi	Lakhmanmandi A .	...	Clayey loam .	29° 10′
	,, . .	,, B .	...	,, ,, .	29° 10′
	Average for Division.	......	...	...	...
		......	...	....	...
		. ....	...	......	...
Pilibhit Division.	Closed Reserves Working Circle I.	Compt. 10 c . .	...	Loamy sand with a fair amount of humus.	28° 42′
	Chuka . .	Compt. 5 e . .	...	Sandy loam with a fair amount of humus.	28° 47′

OF GIRTH GROWTH OF SAL.					MEAN ANNUAL GIRTH INCREMENT.						
					Girth Class.						REMARKS.
Elevation above Mean Sea Level in feet.	Aspect.	Slope.	Mean Annual Rainfall in inches.	Number of Stems.	½′–1½′	1½′–3′	3′–4½′	4½′–6′	6′–8′	All classes up to 6′.	
...	...	...	...	...	...	...	...	...	...	...	No. sample plot.
...	...	...	...	...	...	...	...	...	...	...	"
2,400	...	...	75 to 86	...	...	0·4	0·4	0·3	0·2	0·3	Unthinned.
1,800	...	...	75 to 86	...	0·7	0·2	0·3	0·3	0·5	0·4	"
2,600	...	...	75 to 86	...	...	0·3	0·3	0·4	...	0·3	"
1,800	...	...	75 to 86	...	0·4	0·5	0·9	...	...	0·5	"
...	...	...	...	...	...	...	...	...	...	...	No. sample plot.
...	...	...	...	...	...	...	...	...	...	...	"
1,000	...	...	75 to 86	...	0·2	0·2	0·4	03	...	0·3	Unthinned.
1,000	...	...	75 to 86	...	0·4	0·5	0·5	0·5	0·6	0·5	Thinned.
...	...	...	...	...	0·19	0·31	0·34	0·26	0·46	0·31	Unthinned.
...	...	...	...	...	0·40	0·43	0·42	0·57	0·39	0·44	Thinned.
...	...	...	...	...	0·31	0·35	0·38	0·43	0 44	0·37	Thinned and Unthinned.
625	...	...	50	...	0·34	0·53	0·67	...	...	0·45	......
650 {	...	...	55	...	0·52	0·73	0·83	...	...	0·75	Thinned.
	...	...	...	...	0·61	0·66	0·57	0·53	...	0·61	Unthinned.

Name of Forest Division.	Name of Forest Reserve or Working Circle.	SAMPLE PLOT TO DETERMINE THE RATE			
		Name of Sample Plot.	Geological formation.	Soil and Sub-soil.	Latitude.
Pilibhit Division.—*contd.*	Chuka . .	Compt. 7 e . .	...	Sandy loam rich in humus.	28° 47′
	Neoria . .	Compt. 15 e	...	Sandy loam dry deficient in humus.	28° 48′
	Saunia . .	......	...	...	...
	Dhamela . .	......	...	...	...
	Puranpur .	Compt. 20 e . .	...	Loamy sand with fair amount of humus.	28° 34′
		......	..	...	...
	Average for Division.	......	...	...	...
		......	..	...	...
Kheri Division.	Kanparia West Sal Working Circle.	Sample Plot No. I, Compt. 9 *b*.	...	Alluvium .	28° 35′ 35′
	Kanparia West Sal Working Circle.	Sample Plot No. II, Compt. 14 *b*.	...	" .	28° 34′ 43″
	Kanparia West Sal Working Circle.	Sample Plot No. III, Compt. 30.	...	" .	28° 32′ 38″
	Khairagarh East Sal Working Circle.	Sample Plot No. IV, Compt. 54.	...	" .	28° 27′ 38″
	Khairagarh East Sal Working Circle.	Sample Plot No. V, Compt. 70.	...	" .	28° 25′ 22″
	Kishanpur Working Circle.	Coupe IV . . .	...	" .	28° 19′ 16″

OF GIRTH GROWTH OF SAL.					MEAN ANNUAL GIRTH INCREMENT.						
					Girth Class.						REMARKS.
Elevation above Mean Sea Level in feet.	Aspect.	Slope.	Mean Annual Rainfall in inches.	Number of Stems.	½'—1½'	1½'—3'	3'—4½'	4½'—6'	6'—8'	All classes up to 6'.	
650	...	...	55	...	0·72	0·76	0·73	1·07	...	0·77	Thinned.
				...	0·51	0·94	0·82	1·19	...	0·71	Unthinned.
650	...	...	55	...	0·47	0·63	0·46	...	...	0·56	......
...	...	...	...	...	...	...	...	...	...	...	No sample plot.
...	...	...	...	...	...	...	...	...	...	...	,,
590	...	...	50	...	0·38	0·77	0·79	...	...	0·73	......
...	...	...	...	...	0·66	0·75	0·77	1·07	...	0·76	Thinned.
...	...	...	...	...	0·42	0·69	0·63	1·08	...	0·61	Unthinned.
...	...	...	...	...	0·45	0·70	0·69	1·07	...	0·64	Thinned and Unthinned.
525	...	...	50	...	0·50	0·72	0·80	0·75	...	0·77	High level ground.
514	...	...	50	...	..	0·38	0·50	0·56	0·45	0·49	Low level ground.
498	...	...	50	...	...	0·97	1·10	1·02	1·00	1·04	Phanta belt type.
470	...	...	50	...	...	0·76	0·64	0·70	1·10	0·71	Low level ground.
445	...	...	50	...	...	0·50	0·69	0·73	0·30	0·63	High level ground.
520	...	...	45	...	...	...	...	...	...	...	Only one year's measurements have been recorded.

Name of Forest Division.	Name of Forest Reserve or Working Circle.	SAMPLE PLOT TO DETERMINE THE RATE			
		Name of Sample Plot.	Geological formation.	Soil and Sub-soil.	Latitude.
Kheri Division—*contd.*	Kishanpur Working Circle.	Coupe VI .	...	Alluvium .	28° 23′ 10″
	Marha Working Circle.	„ IV .		„ .	28° 17′ 52″
	Marha Working Circle.	„ VIII . .		„ .	28° 16′ 59″
	Khamaria Working Circle.	......		...	...
	Hirapur Working Circle.	Kataia Coupe V .		Alluvium .	28° 24′ 6″
		Gola „ IV .	...	„	28° 6′ 13″
		„ „ VIII .	...	„	28° 5′ 24″
		Moherena „ IV	...	„ .	28° 9′ 42″
	Average for above existing sample plots.	......	..	...	...
	Average of all sample plots maintained between 1880 and 1902, *vide* paragraph 43, Trans-Sarda Forests Working-' lan.	.....	...	...	..
	Average for Division of all recorded measurements.	......	...	...	.

OF GIRTH GROWTH OF SAL.					MEAN ANNUAL GIRTH INCREMENT.						
					Girth Class.						REMARKS.
Elevation above Mean Sea Level in feet.	Aspect.	Slope.	Mean Annual Rainfall in inches.	Number of Stems.	½′—1½′	1½′—3′	3′—4½′	4½′—6′	6′—8′	All classes up to 6′.	
540	...	...	45	...	...	...	...	...	...	...	Only one year's measurements have been recorded.
533	...	...	45	...	...		...	...	...	...	
529	...	...	45	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	No sample plot.
555	...	...	45	...	...	...	...	...	...	...	No sample plots.
506	...	...	45	..	...	...	...	...	..	...	
505	...	...	45	...	...	...	...	..	...	...	
520	...	...	45	...	...	...	...	...	...	...	
...	...	...	...	...	0·50	0·71	0·78	0·77	0·66	0·75	
...	..	...	...	...	0·60	0·07	0·72	0·64	..	0·65	
...	...	...	...	...	0·55	0·69	0·75	0·71	0·66	0·70	

Name of Forest Division.	Name of Forest Reserve or Working Circle.	SAMPLE PLOT TO DETERMINE THE RATE			
		Name of sample Plot.	Geological formation.	Soil and Sub-soil.	Latitude.
Bahraich Division	Nishangara Working Circle I.	Nishangara Working Circle Sample Plot.	...	Stiff sandy loam.	28° 17′ 7″
	Murtiha Working Circle II.	Working Circle II Plot	...	Rich sandy loam.	28° 11′ 28″
	Motipur Working Circle III.	" " III "	...	Light sandy loam.	28° 6′ 26″
	Babay Working Circle.	......	...	...	...
	Sajauli Working Circle.	......	...	...	...
	Gubbapur .	Coupe No. III . .	...	Sandy loam .	27° 53′ 13″
	" .	" " VII . .	...	" " .	27° 50′ 39″
	Sonpathri .	......	...	...	...
	Gubia . .	Coupe No. V	...	Sandy loam vegetable soil scanty.	27° 45′ 22″
	Sohelwa Working Circle.	......	...	...	...
	Bhinga Working Circle.	......	...	...	...
	Chakia Working Circle.	Plot I Coupe III .	...	Moist rich sandy loam.	28° 4′ 36″
	Chakia Working Circle II.	Compt. XV .	...	Stiff sandy loam.	28° 3′ 3″
	Charda Working Circle III.	Coupe No. IV . .	...	Moist sandy loam.	27° 57′ 24″
	Charda Working Circle III.	" " IX . .	...	Sandy loam	27° 57′ 37″
	Charda Working Circle IV.	" " V . .	...	" " .	27° 55′ 53″
	Average for Division.	......	...	...	...

of Girth growth of Sal.					Mean annual Girth increment.						
					Girth class.						Remarks.
Elevation above Mean Sea Level in feet.	Aspect.	Slope.	Mean Annual Rainfall in inches.	Number of Stems.	½'—1½'	1½'—3'	3'—4½'	4½'—6'	6'—8'	All classes up to 6'.	
...	...	...	...	...	0·39	0·49	0·56	0·66	...	0·51	
...	...	...	...	...	0·36	0·58	0·64	0·68	0·71	0·63	
...	...	...	...	...	0·34	0·42	0·47	0·37	...	0·44	
...	...	...	...	...	...	...	...	...	...	...	No sample plots.
...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	0·42	0·72	...	...	...	0·64	
...	...	...	...	...	0·13	0·39	0·57	...	...	0·39	
...	...	...	...	...	...	...	...	...	...	...	No sample plots.
...	...	...	...	...	...	0·27	0·29	0·33	0·20	0·44	
...	...	...	...	...	...	...	...	...	...	...	No sample plots.
...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	0·17	0·26	0·37	...	...	0·27	
...	...	...	...	...	0·14	0·12	0·20	...	...	0·14	
...	...	...	...	...	...	...	...	...	...	...	Measurements discarded.
...	...	...	...	...	0·34	0·44	0·55	...	...	0·40	
...	...	...	...	...	0·12	0·36	0·65	...	...	0·33	
...	...	...	...	...	0·26	0·42	0·49	0·58	0·29	0·42	

Name of Forest Division.	Name of Forest Reserve or Working Circle.	Sample Plot to determine the rate			
		Name of Sample Plot	Geological formation.	Soil and Sub-soil.	Latitude.
Gonda Division.	Tikri . .	Compt. No. IV	...	Sandy loam .	...
	„ . .	„ „ XII .	...	„ „ .	27° 0′
	Bhambar .	Sakra No. I . .	...	„ „ .	27° 38′
	„ .	„ „ II . .	...	„ „ .	27° 38′
	„ .	Chandanpur No. I .	...	„ „ .	27° 39′
	„ .	„ „ II .	...	„ „ .	27° 39′
	Tulsipur .	......	...	...	...
	Bahalawa .	......	...	...	...
	Grazing Circles	......	...	...	...
	Average for Divison.	......	...	...	...
Gorakhpur Division.	Working Circle I.	Coupe I . .	...	Sandy loam .	26° 43′ 59″
	Working Circle I.	„ II . .	...	„ „ .	26° 45′ 50″
	Working Circle I.	„ III . .	...	„ „ .	26° 43′ 40″
	Working Circle I.	„ IV . .	...	„ „ .	26° 43′ 20″
	Working Circle I	„ V . .	...	„ „ .	26° 43′ 20″
	Working Circle I.	„ VI . .	...	„ „ .	26° 2′ 56″
	Working Circle I.	„ VII . .	...	„ „ .	26° 47′ 11″
	Working Circle I.	„ VIII . .	...	„ „ .	26° 2′ 26″
	Working Circle I.	„ IX . .	...	„ „ .	26° 2′ 54″

OF GIRTH GROWTH OF SAL.					MEAN ANNUAL GIRTH INCREMENT.						
					Girth class.						REMARKS.
Elevation above Mean Sea Level in feet.	Aspect.	Slope.	Mean Annual Rainfall in inches.	Number of Stems.	½′—1½′	1½′—3′	3′—4½′	4½′—6′	6′—8′	All classes up to 6′.	
350	...	...	48·8	...	0·33	0·52	0·83	...	...	0·51	
350	...	...	48·8	...	0·37	0·93	1·08	..	...	0·93	
368	...	...	49·68	...	0·30	0·50	0·62	0·50	...	0·43	
368	...	...	49·68	...	...	...	...	...	...	...	Measurements commenced in 1906.
366	...	...	49·68	...	0·22	0·47	0·83	0·71	...	0·58	
366	...	...	49·68	...	0·34	0·79	0·97	0·82	...	0·76	
...	...	...	...	...	...	...	...	...	...	...	No sample plots.
...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	0·31	0·55	0·86	0·76	...	0·55	
325	...	...	53·5	...	...	...	...	...	...	...	Measurements taken in each sample plot not received.
325	...	...	53·5	...	..	...	...	...	...	...	
325	...	...	53·5	...	...	...	...	...	...	...	
325	...	...	53·5	...	...	..	...	..	...	...	
325	...	...	53·5	...	...	...	...	...	...	...	
325	...	...	53·5	...	...	...	...	...	...	...	
325	...	...	53·5	...	...	...	...	...	...	...	
325	...	...	53·5	...	...	...	...	...	...	...	
325	...	...	53·5	...	...	...	...	...	...	...	

Name of Forest Division.	Name of Forest Reserve or Working Circle.	SAMPLE PLOT TO DETERMINE THE RATE			
		Name of Sample Plot.	Geological formation.	Soil and Sub-soil.	Latitude.
Gorakhpur Division.—*contd.*	Working Circle I.	Coupe X . .	...	Sandy loam .	26° 46′ 37″
	Working Circle I.	„ XI . .	...	„ „ .	26° 45′ 4″
	Work ng Circle I.	„ XII . .	...	„ „ .	26° 45′ 50″
	Workin Circle I.	„ XIII . .	...	„ „ .	26° 43′ 59″
	Working Circle I.	„ XIV . .	...	„ „ .	26° 44′ 40″
	Working Circle II*a*.	„ I . .	...	„ „ .	27° 4′ 58″
	Working Circle II*a*	„ II . .	...	„ „ .	27° 7′ 10″
	Working Circle II*a*.	„ III . .	...	„ „ .	27° 11′ 5″
	Working Circl II*a*.	„ IV . .	...	„ „ .	27° 13′ 4″
	Working Circle II*a*.	„ V . .	...	„ „	27° 12′ 15″
	Working Circle II*a*.	„ VI . .	...	„ „	27° 10′ 47″
	Working Circle II*a*.	„ VII . .	...	„ „ .	27° 10′ 40″
	Working Circle II*a*.	„ VIII . .	...	„ „ .	27° 10′ 4″
	Working Circle II*a*.	„ IX .	...	„ „ .	27° 9′ 34″
	Working Circle II*a*.	„ X . .	...	„ „ .	27° 9′ 3″
	Working Circle II*a*.	„ XI . .	...	„ „ .	27° 0′ 49″
	Working Circle II*a*.	„ XII . .	...	„ „ .	27° 0′ 49″

of Girth growth of Sal.					Mean annual Girth increment.						
					Girth class.						
Elevation above Mean Sea Level in feet.	Aspect.	Slope.	Mean Annual Rainfall in inches.	Number of Stems.	½′–1½′	1½′–3′	3′–4½′	4½′–6′	6′–8′	All classes up to 6′.	Remarks.
325	...	...	53·5	...	...	...	...	...	...	...	
325	...	...	53·5	...	...	...	...	...	...	...	
325	...	...	53·5	...	...	...	...	...	...	...	
325	...	...	53·5	...	...	...	...	...	...	...	
325	...	...	53·5	...	...	...	...	...	...	...	
325	...	...	53·5	...	...	...	...	...	...	...	
325	...	...	53·5	...	...	...	...	...	...	...	
325	...	...	53·5	...	...	...	...	...	...	...	
325	...	...	53·5	...	...	...	...	...	...	...	
325	...	...	53·5	...	...	...	...	...	...	...	
325	...	...	53·5	...	...	...	...	...	...	...	
325	...	...	53·5	...	...	...	...	...	...	...	
325	...	...	53·5	...	...	...	...	...	...	...	
325	...	...	53·5	...	...	...	...	...	...	...	
325	...	...	53·5	...	...	...	...	...	...	...	
325	...	...	53·5	...	...	...	...	...	...	...	
325	...	...	53·5	...	...	...	...	...	...		

Name of Forest Division.	Name of Forest Reserve or Working Circle.	SAMPLE PLOT TO DETERMINE THE RATE			
		Name of Sample Plot.	Geological formation.	Soil and Sub-soil.	Latitude.
Gorakhpur Division—*contd.*	Working Circle II*a*.	Coupe XIII . .	...	Sandy loam .	27° 0′ 2″
	Working Circle II*a*.	" XIV . .	...	" " .	27° 9′ 32″
	Working Circle II*b*.	" I . .	...	" " .	26° 58′ 16″
	Working Circle II*b*.	" II . .	...	" " .	26° 57′ 36″
	Working Circle II*b*.	" III . .	...	" "	26° 57′ 36″
	Working Circle II*b*.	" IV . .	...	" " .	26° 57′ 45″
	Working Circle II*b*.	" V . .	...	" " .	26° 58′ 30″
	Working Circle II*b*.	" VI . .	...	" " .	26° 57′ 32″
	Working Circle II*b*.	" VII . .	...	" " .	26° 55′ 40″
	Working Circle II*b*.	" VIII . .	...	" " .	26° 55′ 40″
	Working Circle II*b*.	" IX . .	...	" " .	26° 57′ 10″
	Working Circle II*b*.	" X . .	...	" " .	26° 55′ 20″
	Working Circle II*b*.	" XI . .	...	" " .	26° 57′ 10″
	Working Circle II*b*.	" XII . .	...	" " .	26° 55′ 10″
	Working Circle II*b*.	" XIII . .	...	" " .	25° 57′ 10″
	Working Circle II*b*.	" XIV . .	...	" " .	26° 57′ 10″
	Working Circle III.	East Lehra . .	...	" "	27° 18′ 0″

OF GIRTH GROWTH OF SAL.					MEAN ANNUAL GIRTH INCREMENT.						
					Girth class.						
Elevation above Mean Sea Level in feet.	Aspect.	Slope.	Mean Annual Rainfall in inches.	Number of Stems.	$\frac{1}{2}'$–$1\frac{1}{2}'$	$1\frac{1}{2}'$–$3'$	$3'$–$4\frac{1}{2}'$	$4\frac{1}{2}'$–$6'$	$6'$–$8'$	All classes up to $6'$.	REMARKS.
325	...	...	53·5	...	...	...	...	...	...	...	
325	...	...	53·5	...	...	...	...	...	...	...	
325	...	...	53·5	...	...	...	...	...	...	...	
325	...	...	53·5	...	...	...	...	...	...	...	
325	...	...	53·5	...	...	...	...	...	...	...	
325	...	...	53·5	...	...	...	...	...	...	...	
325	...	...	53·5	...	...	...	...	...	...	...	
325	...	...	53·5	...	...	...	...	...	...	...	
325	...	...	53·5	...	...	...	...	...	...	...	
325	...	...	53·5	...	...	...	...	...	...	...	
325	...	...	53·5	...	...	...	...	...	...	...	
325	...	...	53·5	...	...	...	...	...	...	...	
325	...	...	53·5	...	...	...	...	...	...	...	
325	...	...	53·5	...	...	...	...	...	...	...	
325	...	...	53·5	...	...	...	...	...	...	...	
325	...	...	53·5	...	...	...	...	...	...	...	
325	...	...	53·5	...	...	...	...	...	...	...	

Name of Forest Division.	Name of Forest Reserve or Working Circle.	SAMPLE PLOT TO DETERMINE THE RATE			
		Name of Sample Plot.	Geological formation.	Soil and Sub-soil.	Latitude.
Gorakhpur Division—*concld.*	Working Circle III.	Dudhai	...	Sandy loam .	27° 11' 1"
	Working Circle IV.	......	...	" " .	..
	Working Circle V.	Daibhar	...	" " .	27° 19' 46"
	Working Circle V.	Chawk	...	" " .	27° 17' 12"
	Working Circle VI.	......	...	" " .	...
	Average for Division.	...	...	...	...

II.—The East
A—BEN

Darjeeling Division.	Tista Valley .	Sample Plot A. Badamtan.	...	Stony; little soil.	27° 5'—26° 59'
	" " .	Sample Plot B. Pashok	...	Sandy loam .	
	" " .	" " C. Riang	...	Light and full of stones.	
	Average for Division.	.. ..	...	......	...
Tista Division.	Tista . .	Rangpo	...	Dry rocky ridge.	27° 10'
	" . .	Mangchu . .	...	Deep rich alluvial river flat.	27° 10'
	" . .	Mngbur .	...	Dry rocky ridge.	27° 5'
	Chel . .	Mongphong . . .	...	Light sandy soil, old river flat.	26° 50'
	Average for Division.	......	...	......	...

OF GIRTH GROWTH OF SAL.					MEAN ANNUAL GIRTH INCREMENT.						
					Girth class.						REMARKS.
Elevation above Mean Sea Level in feet.	Aspect.	Slope.	Mean Annual Rainfall in inches.	Number of Stems.	½′–1½′	1½′–3′	3′–4½′	4½′–6′	6′–8′	All classes up to 6′.	
325	...	...	53·5	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	..	
325	...	...	53·5	...	...	...	...	...	...	...	
325	...	...	53·5	...	...	...	...	...	..	...	
...	...	...	...	...	...	...	...	...	...	..	
...	...	...	...	...	0·37	0·50	0·57	0·65	0·41	0·50	

Himalayan Tract.

GAL.

2,000	...	...	60	...	...	0·81	0·72	0·56	...	0·75	
2,500	...	...	70	...	...	0·57	0·75	0·60	...	0·59	Light thinnings.
1,500	...	...	100	...	...	0·39	0·56	0·69	...	0·53	
...	...	...	...		...	0·59	0·68	0·62	...	0·62	
2,000	...	...	100	...	...	...	0·53	0·36	0·39	0·42	
1,500	...	...	100	...	...	...	1·45	1·01	0·83	1·01	
2,000	...	...	100	...	...	...	0·53	0·36	0·49	1·46	
500	...	...	150 to 180	...	...	...	...	...	...	..	No figures reported.
...	...	...	...	...	...	...	0·84	0·58	0·57	0·66	

Name of Forest Division.	Name of Forest Reserve or Working Circle.	SAMPLE PLOT TO DETERMINE THE RATE			
		Name of Sample Plot.	Geological formation.	Soil and Sub-soil.	Latitude.
					A—BEN
Kurseong Division.	Sukna (Terai series).	Bamanpokri	...	River gravel beneath a light sandy loam deep with good layer of humus.	26° 48′
	Sukna (Terai series).	Taipu	...	River gravel-soil a sandy loam.	26° 46′
	Sukna (Terai series).	Panchanai	...	River gravel-soil a light sandy loam.	26° 47′
	Sukna (Terai series).	West Sivoke	...	River gravel-soil a deep sandy loam.	26° 48′
	Sukna (Terai series).	North „	...	River gravel, deep sandy loam.	26° 48′
	Sukna (Hill series).	Sivoke	...	Gneiss, sandy clay.	26° 47′
	Sukna (Hill series.)	Berrik	...	Gneiss, light sandy loam.	26° 50′
	Average for Division.	......	...	......	...
					B—EASTERN BENGAL
Jalpaiguri Division.	Apalchand	Katanbari	...	Sandy loam	26° 44′
	Lower Tondu	Garabmara	...	„ „	26° 30′
	Upper Tondu	......	...	......	26° 37
	Muraghat	......	...	......	26° 40′
	Average for Division.	......	...	......	...

OF GIRTH GROWTH OF SAL.					MEAN ANNUAL GIRTH INCREMENT.						
					Girth class.						REMARKS.
Elevation above Mean Sea Level in feet.	Aspect.	Slope.	Mean Annual Rainfall in inches.	Number of Stems.	½′—1½′	1½′—3′	3′—4½′	4½′—6′	6′—8′	All classes up to 6′.	
SAL—*contd.*											
900	...	...	151	...	0·11	0·69	0·91	...	...	0·70	
600	...	...	133·29	...	0·27	0·43	0·04	0·06	...	0·44	
500	...	...	158·64	...	...	0·73	0·10	1·26	0·75	1·09	
600	...	...	159·64	...	0·54	0·71	0·95	1·03	...	0·73	
600	...	...	160	...	...	0·57	0·91	0·96	0·45	0·85	
600—800	...	...	161	...	...	...	...	...	...	...	Opened in 1907. Rainfall estimated.
850	...	...	162	...	...	...	...	...	...	...	
...	...	...	...	...	0·31	1·04	0·97	1·10	0·40	0·76	
AND ASSAM											
329	...	...	130·52	...	·62	0·58	0·61	..	...	0·60	From ring countings.
329	...	...	157·36								
...	...	...	...	...	...	...	...	...	...	...	No sample plot.
...	...	...	...	...	...	...	...	...	...	...	No sample plot.
...	...	...	...	...	·62	0·58	0·61	...	...	0·60	

Name of Forest Division.	Name of Forest Reserve or Working Circle.	SAMPLE PLOT TO DETERMINE THE RATE			
		Name of Sample Plot.	Geological formation.	Soil and Sub-soil.	Latitude.
					B.—EASTERN BENGAL
Buxa Division.	Buxa . .	Rajabhatkhawa A	...	Deep sandy loam.	26° 36′ 50″
	" . .	" B .	...	Deep sandy loam.	26° 36′ 49″
	" . .	" C	...	Deep sandy clayey loam	26° 36′ 17″
	" .	Dina in Rimatong .	...	Sandy loam with good layer of humus.	26° 41′ 57″
	" .	Bala in Panbari	...	Sandy loam with thin layer of humus.	26° 41′ 46″
	Baroghar .	......	...	......	...
	Haldibari	......	...	......	...
	Average for Division.	......	...	......	...
Goalpara Division.	Western Circle	......	...	......	...
	Eastern Circle .	......	...	......	...
	Guma .	......	...	......	...
	Average for Division.	......	...	......	...

OF GIRTH GROWTH OF SAL.					MEAN ANNUAL GIRTH INCREMENT.						REMARKS.
					Girth class.						
Elevation above Mean Sea Level in feet.	Aspect	Slope.	Mean Annual Rain-fall in inches.	Number of Stems.	½′—1½′	1½′—3′	3′—4½′	4½′—6′	6′—8′	All classes up to 6′.	
AND ASSAM.—*contd.*											
1,000	...	...	157	...	..	...	0·56	0·62	...	0·64	
1,000	...	...	157	...	...	...	0·68	0·63	...	0·66	
1,000	...	...	157	...	...	0·69	0·90	0·71	...	0·59	
1,500	...	...	157	...	.	...	0·59	0·77	...	0·68	
1,500	...	...	157	...	...	..	0·33	0·68	0·63	0·43	
...	...	...	...	...	...	...	...	...	...	...	No sample plot.
...	...	...	...	...	...	...	...	...	...	...	No sample plot.
...	...	...	...	...	...	0·69	0·61	0·68	0·63	0·60	
...	...	...	...	...	...	..	...	...	...	...	
...	...	...	...	...	0·62	0·55	0·69	...	..	0·63	From ring countings. Increment calculated from 424 sample trees.
...	...	...	...	...	...	0·43	0·67	0·71	...	0·60	
...	...	...	...	...	0·62	0·49	0·68	0·71	...	0·62	

Name of Forest Division.	Name of Forest Reserve or Working Circle.	Sample Plot to determine the rate			
		Name of Sample Plot.	Geological formation.	Soil and Sub-soil.	Latitude.
				B.—Eastern Bengal	
Garo Hills Division.	Dambu . .	Sample Plot No. I .	...	Rich loam covered with light grass. Pebbles and stones underneath.	25° 41′ 15″
	" . .	" " No. II .	...	Poor sandy loam 6″ deep.	25° 41′ 15″
	" . .	" " No. III .	...	Rich clayey loam.	25° 41′ 15″
	" .	" " No. IV .	...	Poor sandy loam.	25° 41′ 15″
	" . .	" " No. V .	...	Poor loam without any boulders or surface rocks, covered with light grass, and ikra grass.	...
	Darugiri . .	Sample Plot No. I .	...	Poor and shallow in places stony especially in east. A little surface rock. No humus.	...
	Average for Division.	......	...	...	...
Darrang Division.	Sal Working Circle.	......	...	Loam . .	26° 55′

OF GIRTH GROWTH OF SAL.					MEAN ANNUAL GIRTH INCREMENT.						
					Girth class.						REMARKS.
Elevation above Mean Sea Level in feet.	Aspect.	Slope.	Mean Annual Rainfall in inches.	Number of Stems.	½′—1½′	1½′—3′	3′—4½′	4½′—6	6′—8′	All classes up to 6′.	
AND ASSAM—*contd.*											
1,000 to 1,500	...	...	120	...	0·22	0·39	0·66	0·19	0·47	0·38	
1,000 to 1,500	...	...	120	...	0·19	0·18	0·14	0·33	0·22	0·21	
1,000 to 1,500	...	...	120	...	0·13	0·18	0·19	0·33	0·21	0·21	
1,000 to 1,500	...	...	120	...	0·37	0·27	0·25	0·32	0·27	0·29	
1,000 to 1,500	...	...	120	...	0·18	0·29	0·24	0·23	0·21	0·23	
1,000	...	..	120	...	0·14	0·17	0·66	0·43	...	0·35	
...	...	...	...	..	0·20	0·25	0·36	0·30	0·23	0·28	
...	...	...	90	...	0·47	0·59	0·58	..	...	0·55	Ring countings: but a sample plot has now been selected.

Name of Forest Division.	Name of Forest Reserve or Working Circle.	Sample Plot to determine the rate			
		Name of Sample Plot.	Geological Formation.	Soil and Sub-soil.	Latitude.
					B.—Eastern Bengal
Nowgong Division.	Kukrakata .	......	...	...	...
	Diju . .	......	...	...	...
	Suang . .	......	..	...	...
	Bamuni . .	......	...	...	...
	Rong Khong .	......	...	...	...
	Dabaka . .	......	...	...	...
	Sildharampur .	......	...	...	...
	Duar Jungthung	......	..	...	...
	Chilabar . .	......	...	...	...
	Sonaikhusi .	......	...	...	...
	Kalahat . .	......	...	...	...
	Average for Division.	......	...	...	...
Kamrup Division.	Rani Reserve .	......	...	...	...
	Kawasing .	.. ...	...	...	...
	Jarasal . .	......	...	...	...
	Mataikhar .	......	...	...	...
	Kulsi . .	......	...	...	...
	Melmillia . .	......	...	...	...
	Chhaygaon .	......	...	...	...
	Pantan . .	......	...	...	...

OF GIRTH GROWTH OF SAL. — MEAN ANNUAL GIRTH INCREMENT.

AND ASSAM—*concld.*

Elevation above Mean Sea Level in feet.	Aspect.	Slope.	Mean Annual Rainfall in inches.	Number of Stems.	Girth Class. ½′—1½′	1½′—3′	3′—4½′	4½′—6′	6′—8′	All classes up to 6.′	REMARKS.
...	...	...	...	...	...	...	...	...	...	...	No sample plots.
...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	
...	...		...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	No sample plots.
...	...	...	...	...	...	...	...	...	...	...	No sample plots.
...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	

Name of Forest Division.	Name of Forest Reserve or Working Circle.	SAMPLE PLOT TO DETERMINE THE RATE			
		Name of Sample Plot.	Geological formation.	Soil and Sub-soil.	Latitude.
Kamrup Division.	Mayang . .	......	...	...	...
	Barduar . .	......	...	...	...
	Barjuli . .	......	...	...	...
	Jaipur . .	......	...	...	..
	Nampathar .	......	...	...	...
	Boradobhe .	......	...	...	...
	Gezang . .	......	...	...	...
	Jharakhuri .	......	...	...	...
	Mugakhal Reserve.	......	...	...	...
	Sursuria . .	......	...	...	...
	Khurkhuri .	......	...	...	...
	Garubaldha .	......	...	...	...
	Taraibari .	......	...	...	...
	Ghoraputa .	......	...	...	...
	Khatkhati .	......	...	...	...
	Khuksisikrabura	......	...	...	...
	Dumpara . .	......	...	...	...
	Simla . .	......	...	...	...
	Dudkhuri	......	...	...	...

The Central

A—BEN

Sonthal Pargannahs.	Old Reserve .	Magdiha . . .	..	Laterite soil proportions of iron, manganese, sand and clay. Surface covered with rocky boulders more or less all over.	24° 18′

OF GIRTH GROWTH OF SAL.					MEAN ANNUAL GIRTH INCREMENT.						
					Girth Class.						
Elevation above Mean Sea Level in feet.	Aspect.	Slope.	Mean Annual Rainfall in inches.	Number of Stems.	½'–1½'	1½'–3'	3'–4½'	4½'–6'	6'–8'	All classes up to 6'.	REMARKS.
...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	No sample plot.
...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	

Indian Tract.

GAL.

800	...	...	60	.	0·45	0·35	0·38	...	...	0·39	

Name of Forest Division.	Name of Forest Reserve or Working Circle.	Sample Plot to determine the rate: Name of Sample Plot	Geological formation.	Soil and Sub-soil.	Latitude.
The Central					
A—Ben					
Sonthal Pargannahs—*cont.*	Old Reserve	Kulkath	...	Laterite soil proportions of iron, manganese, sand and clay. Surface covered with rocky boulders more or less all over.	24° 18′
	" "	Khatanji	...	Ditto	24° 30′
	Average for Division.	......	...	...	...
Palamau Division.	Palamau Reserve, Southern Range.	Maramand	.	Sandy clay	...
	Palamau Reserve. Northern Range.	Lat.	...	Micaceous sandy clay.	...
		Koderma	...	Sandy clay	...
	Average for Division.	......	...	...	...
Singhbhum Division.	Saitba	......	...	...	...
	Santara	.. ...	...	...	..
	Kolhan	Leda	...	...	..
	Samta	Samta	...	...	...
	"	Tiripoli	...	...	...
	Porahat	Birda	...	...	...
	Koina	......	...	...	...
	Average for Division.	......	...	...	...

OF GIRTH GROWTH OF SAL.					MEAN ANNUAL GIRTH INCREMENT.						REMARKS.
					Girth Class.						
Elevation above Mean Sea Level in feet.	Aspect.	Slope.	Mean Annual Rainfall in inches.	Number of Stems.	¼′–1½′	1½′–3′	3′–4½′	4½′–6′	6′–8′	All classes up to 6′	
Indian Tract—*contd.*											
GAL—*contd.*											
900	...	...	60	...	0·95	0·56	...	...	...	0·75	
1,000	...	...	60	...	1·50	0·54	·62	...	...	0·59	
...	...	...	...	...	0·97	0·48	0·50	...	...	0·68	
1,200	..	...	64·13	...	0·28	0·40	...	...	...	0·34	Unthinned.
1,200	...	...	53·82	...	0·38	0·56	0·60	...	...	0·51	Thinned.
					0·24	0·33	0·04			0·20	Unthinned.
1,250	...	...	46·91	...	...	...	...	...	...	...	Coppice area.
...	...	...	...	...	0·38	0·56	0·60	...	...	0·51	Thinned.
					0·26	0·36	0·04	...	...	0·22	Unthinned.
					0·32	0·46	0·32	...	...	0·36	Thinned and unthinned both combined.
...	...	...	...	...	...	...	...	...	...	...	No sample plots.
...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	0·25	0·30	0·39	0·31	
...	...	...	...	...	...	...	0·59	0·39	0·42	0·47	
...	...	...	...	...	...	...	0·53	0·59	...	0·56	
...	...	...	...	...	...	...	0·11	0·20	.	0·15	
...	...	...	...	...	...	...	...	...	...	...	No sample plot.
...	...	...	...	...	...	...	0·37	0·37	0·40	0·38	

Name of Forest Division.	Name of Forest Reserve or Working Circle.	SAMPLE PLOT TO DETERMINE THE RATE			
		Name of Sample Plot.	Geological formation.	Soil and Sub soil	Latitude.
					A— BEN
Chaibassa Division.	Protected Forests.	......	...	......	...
	Average for Division.	......	...	......	...
Puri Division.	Chandka	Haripur	...	Light sandy loam overlying laterite.	20°16′
	Khurda	Joymangal	...	Light, sandy loam overlying laterite.	20°13′
	Banpur	Kodalikhat	...	Fertile, sandy loam of good depth overlying grass with gentle surface slope.	19°55′
	Do.	Kodnapada	...	Fertile, sandy loam of good depth overlying grass with gentle surface slope.	19°52′
	Do	Rajon	...	Fertile, sandy loam of good depth overlying grass with gentle surface slope.	19°53′
	Do.	Tangiapada	...	Fertile, sandy loam of good depth overlying grass with gentle surface slope	19°53′
	Average for Division.	......	...	......	

OF GIRTH GROWTH OF SAL.					MEAN ANNUAL GIRTH INCREMENT.						REMARKS.
					Girth Class.						
Elevation above Mean Sea Level in feet.	Aspect.	Slope.	Mean Annual Rain-fall in inches.	Number of Stems.	½'—1½'	1½'—3'	3'—4½'	4½'—6'	6'—8'	All classes up to 6'.	
GAL—*contd.*											
...	...	...	...	...	...	...	...	...	...	...	No sample plot.
...	...	...	...	...	...	..	...	...	...	...	
500	...	...	60	...	0·42	0·45	...	...	...	0·44	Abolished since 1907.
500	...	...	60	...	0·31	0·24	...	...	...	0·27	
1,500	...	...	55	...	...	0·34	0·39	0·64	0·50	0·47	
100	...	...	55	...	...	0·32	0·41	0·51	...	0·41	
1,800	...	...	55	...	...	0·37	0·35	0·44	...	0·39	
1,800	...	...	55	...	...	0·24	0·24	0·24	...	0·24	
...	...	...	...	...	0·36	0·33	0·35	0·46	0·50	0·37	

Name of Forest Division.	Name of Forest Reserve or Working Circle.	SAMPLE PLOT TO DETERMINE THE RATE			
		Name of Sample Plot.	Geological formation.	Soil and Sub-soil	Latitude.
					A —BEN
Angul Division.	Raigoda	Rosonda	...	Rich loam	20°41′ to 20°37′
	Do.	Nimbachally	...	Poor sandy loam.	20°37′ to 20°33′
	Do.	Sotidanak	...	Sandy loam, rocky.	20°37′ to 20°33′
	Tulka	....	...	......	...
	Tikerpura	Chotamunda	...	Poor sandy loam, rocky.	20°45′ to 20°41′
	Do.	Purnakote	...	Rich loam	20°41′ to 20°37′
	Durgapur	......	...	...	...
	Average for Division.	......	...	...	...
Sambalpur Division.	Sambalpur Range.	Ludladi	...	Fairly deep loam containing a good amount of humus.	21°0′
	Do.	Kusamura	...	The soil is not very rich, being a light loam without much humus and is similar to that found in all good Sal areas situated on level ground.	21°0′
	Do.	Nyakdongri	...	As above.	21°0

OF GIRTH GROWTH OF SAL. — MEAN ANNUAL GIRTH INCREMENT.

GAL—*contd.*

Elevation above Mean Sea Level in feet.	Aspect.	Slope.	Mean Annual Rainfall in inches.	Number of Stems.	Girth Class. ½′—1½′	1½′—3′	3′—4½′	4½′—6′	6′—8′	All classes up to 6′.	REMARKS.
1,700	...	...	50	...	...	...	0·59	0·67	0·71	0·66	
1,3 0	...	...	50	...	...	...	0·72	0·61	0·74	0·69	
1,600	...	...	46	...	...	...	0·26	0·48	0·51	0·42	
...	...	...	...	...	...	...	...	...	...	...	No sample plot.
675	...	...	46	...	...	...	0·49	0·3	0·43	0·41	
600	...	...	46	...	...	...	0·55	0·58	...	0·56	
...	...	...	...	...	...	...	...	...	...	...	No sample plot.
...	...	...	...	...	...	...	0·52	0·53	0·60	0·55	
500	...	...	62	...	...	0·26	0·35	0·38	...	0·32	
500	...	Level	62	...	...	0·27	0·27	0·33	0·25	0·28	
750	...	Level	62	...	...	0·29	0·32	0·34	...	0·32	

Name of Forest Division.	Name of Forest Reserve or Working Circle.	SAMPLE PLOT TO DETERMINE THE RATE			
		Name of Sample Plot.	Geological Formation.	Soil and Sub-soil.	Latitude.
A—BEN					
Sambalpur Division —*contd.*	Sambalpur Range.	Bhagatpali . .	...	A light loam in which the presence of clay is more conspicuous containing practically no humus.	21°10′
	Barapahar Range.	......	...	...	...
	Average for Division.	......	...	...	...
B—CENTRAL					
Jubbulpore Division.	Machmacha .	......	...	......	...
	Khitoli .	......	...	......	...
	Karela . .	......	...	......	...
	Seotri . .	......	...	......	...
	Average for Division.	......	...	......	...
Mandala Division.	Banjar Valley	......	...	......	...
	Motinala .	......	...	......	...
	South Phen .	......	...	......	...
	North Phen .	......	...	......	...
	Average for Division.	......	...	......	...

OF GIRTH GROWTH OF SAL.					MEAN ANNUAL GIRTH INCREMENT.						
					Girth Class.						
Elevation above Mean Sea Level in feet.	Aspect.	Slope.	Mean Annual Rainfall in inches.	Number of Stems	½'–1½'	1½'–3'	3'–4½'	4½'–6'	6'–8'	All classes up to 6'.	REMARKS.
GAL—*concld.*											
...	..	...	62	..	...	0·55	0·70	...	...	0·62	
...	...	...	...	...	...	...	...	...	...	...	No sample plot.
...	...	...	...	...	...	0·34	0·41	0·35	0·25	0·34	
PROVINCES.											
...	...	..			...	...	...	...	...	...	No sample plots.
...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	.	...	...	
...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	
	...	...	...	...	...	...	...	...	...	...	Sample plots have been provided in Working-Plan: but none yet established.
...	.	...	...	...	..	...	...	...	...	...	
...	...	...	...		...	...	..	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	
...		...	...	...	...	...	...	...	..	...	

Name of Forest Division.	Name of Forest Reserve or Working Circle.	SAMPLE PLOT TO DETERMINE THE RATE			
		Name of Sample Plot.	Geological formation.	Soil and Sub- Soil.	Latitude.
					B—CENTRAL
Balaghat Division.	Baihar Range .	......	...	......	...
	Raigarh Range	Topla No. I .	...	......	...
	" "	" II .	...	......	...
	" "	" II .	...	......	...
	" "	" IV .	...	......	...
	" "	" V .	...	......	...
	" "	Kuilikhapa No. VI .	...	......	...
	Average for Division.	......	...	......	...
Bilaspore Division.	Lormi . .	......	...	......	...
	Sonakhan .	......	...	......	...
	Average for Division.	......	...	......	...
Raipur Division.	North Sihawa .	......	...	......	...
	South "	......	...	......	...
	Kantranala .	......	...	......	...
	Average for Division.	......	...	......	...

OF GIRTH GROWTH OF SAL.					MEAN ANNUAL GIRTH INCREMENT.						REMARKS.
					Girth Class.						
Elevation above Mean Sea Level in feet.	Aspect.	Slope.	Mean Annual Rainfall in inches.	Number of Stems	½'—1½'	1½'—3'	3'—4½'	4½'—6'	6'—	All classes up to 6.'	
PROVINCES—*contd.*											
...	...	Level ground.	...	...							
...	...		...	...							
...	...		...	...							
...	...		...	...	0·29	0·33	0·32	0·38	0·35	3·33	
...	...		...	...							
...	...		...	...							
...	...		...	...							
...	...	...	...	...	0·29	0·33	0·32	0·38	0·35	0·33	
...	...	...	...	...	...	...	...	...	...	...	No sample plots.
...	...	...	...	...	...	...	...	...	...	..	
...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	No sample plots.
...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	

At this stage it is impossible to generalise or to deduce reliable conclusions from the figures given in the preceding statement. It is admitted that many of the sample plots have been badly chosen ; measurements are in some cases inaccurate or, for obvious reasons, deceptive ; and the trees have almost invariably developed under most abnormal conditions. But, even ignoring these blemishes, it is clear that each sample plot should be carefully and separately studied in order that the quality of the locality (*soil, climate, spring-water level, etc.*) and the effects of the sylvicultural treatment may be correctly gauged, and given their full value. The importance of such investigations is only too manifest. In the preparation of Indian Working-Plans, almost without exception, the rate of girth growth enters into the calculation of the possibility ; and whilst an over-estimation of the mean annual girth increment will lead to over-exploitation, under-estimation by unnecessarily lengthening the rotation may cause serious financial loss.

Bearing these remarks in mind, it may be interesting to consider broadly and over large tracts, how far the data at present available give any indication as to the effect of the different factors of locality on the rate of girth growth, (excluding soil, which in itself is of the greatest importance). This will be facilitated by a reference to the following statement, which contains a summary by Forest Divisions of the preceding data.

Name of Province.	Name of Forest Division.	Latitude.	Longitude.	Altitude above Mean Sea Level in feet.	Mean Annual Rainfall in inches.	Mean annual Girth increment.						Remarks.
						6″—1½′.	1½′—3′.	3′—4½′.	4½′—6′.	6′—8′.	All classes 6′—8′.	
I.—The Plains and Sub-Himalayan tract of the United Provinces, including the Simla Division, Punjab.												
Punjab	Kangra	32° 47′—32° 2′	76° 10′—76° 37′	1,800′—4,000′	62″—110″	...	...	..	...	...	...	
	Simla	30° 27′—30° 19′	77° 33′—77° 38′	1,000′—2,000′	63·50″	0·83	0·71	0·64	...	...	0·72	
	Jaunsar	30° 32′	77° 55′	1,800′—2,000′	80·99″	...	...	...	...	...	.	
Bnited Provinces of Agra & Oudh.	Dehra Dun	30° 17′—29° 55′	77° 40′—78° 20′	1,000′—2,000′	50″—86″	0·41	0·46	0·45	0·51	0·26	0·46	
	Saharanpur					0·53	...	...	...	...	...	
	Ganges	30°—29° 30′	78° 15′—78° 50′	1,000′—4,000′	45″—90″	0·36	0·39	0·47	0·58	0·35	0·41	
	Garhwal	29° 50′—29° 20′	78° 45′—79° 15′	750′—4,000′	40″—118″	0·34	0·57	0·60	0·63	0·52	0·55	
	Naini Tal	29° 20′—29° 16′	79° 25′—79° 34′	2,000′—4,500′	90″	...	...	...	...	...	...	
	Kumaun	29° 30′—29°	79° 15′—80° 20′	750′—5,890′	77″—5″	0·31	0·35	0·38	0·43	0·44	0·37	
	Pilibhit	28° 57′—28° 28′	79° 50′—80° 20′	598′—640′	50′—55″	0·45	0·70	0·69	1·07	...	0·64	
	Kheri	28° 41′—28° 5′	80° 21′—80° 38′	480′—602′	45′—50″	0·55	0·69	0·75	0·71	0·66	0·70	
	Bahraich	28° 24′—27° 40′	81° 10′—82° 15′	400′—3,000′	41″—50″	0·26	0·42	0·49	0·58	0·29	0·42	
	Gonda	27° 49′—26° 58′	82° 15′—82° 45′	550′—2,500′	49′—68′	0·31	0·55	0·86	0·76	...	0·55	
	Gorakhpur	27° 24′—26° 42′	83° 15′—83° 49′	325′	53·5″	0·37	0·50	0·57	0·65	0·41	0·50	
II.—East Himalaya Tract.												
Bengal	Darjeeling	27° 5′—26° 59′	88° 26′—88° 30′	620′—4,000′	175″	...	0·59	0·68	0·62	..	0·62	
	Tista	27° 11′—26° 52′	88° 29′—88° 45′	300′—2,000′	150′—180″	...	...	0·84	0·58	0·57	0·66	
	Kurseong	26° 50′—26° 46′	88° 22′—88° 25′	431′—1,903′	133″—162″	0·31	1·04	0·97	1·10	0·40	76	

Name of Province.	Name of Forest Division.	Latitude.	Longitude.	Altitude above Mean Sea Level in feet.	Mean Annual Rainfall in inches.	Mean Annual Girth Increment. 6"—1½'.	1½'—3'.	3'—4½'.	4½'—6'.	6'—8'.	All classes 6'—8'.	Remarks.
	II.—East Himalaya Tract—*contd.*											
Eastern Bengal & Assam	Jalpaiguri	26° 49'—26° 40'	88° 33'—89° 5'	300'—400'	130"—157"	...	...	...	...	...	...	
	Buxa	26° 52'—26° 28'	89° 21'—89° 55'	859'—4,222'	157"	...	0·69	0·61	0·68	0·63	0·60	
	Goalpara	27°—26° 30'	90'—91'	175'—1,158'	153"	0·62	0·49	0·68	0·71	...	0·62	
	Garo Hills	25° 43'—25° 36'	90° 46'—90° 54'	1,000'—1,500'	120"	0·20	0·25	0·36	0·30	0·23	0·28	
	Darrang	26° 55'—26° 40'	92° 30'—92° 50'	250'—1,000'	90"	...	...	...	...	...	...	
	Nowgong	26° 30'—26°	92° 15'—93° 10'	250'—1,000'	77"	...	...	...	...	...	...	
	Kamrup	26° 15'—25° 45'	91°—91° 45'	150'—1,575'	67"—90"	...	...	...	...	...	...	
	III.—Central India Tract.											
Bengal	Sonthal Parganahs.	25° 15'—24° 18'	87° 23'—87° 50'	500'—1,600'	53·40"	...	0·48	0·50	...	...	...	
	Palamau	24° 36'—23° 28'	86° 30'—84° 2'	564'—4,479'	51·29"	0·32	0·46	0·32	...	...	0·36	
	Singhbhum	22° 50'—22° 2'	85°—85° 20'	750'—3,000'	53·65"	...	...	0·37	0·37	0·40	0·38	
	Chaibassa	23° 9'—22° 0'	85° 20'—86° 43'	1,447'—2,673'	...	...	...	...	...	...	...	
	Puri	20° 26'—19° 41'	84° 59'—85° 56'	500'—3,000'	56·94"	0·36	0·33	0·35	0·46	0·50	0·37	
	Angul	21° 11'—20° 32'	84° 18'—85° 43'	600'—1,700'	46·33"	...	...	0·52	0·53	0·60	0·55	
	Sambalpur	21° 48'—21° 10'	83° 25'—84° 22'	436'—2,341'	67·39"	...	0·34	0·41	0·35	0·25	0·34	
Central Provinces.	Jubbulpore	23° 53'—23° 40'	80° 45'—81°	1,200'—1,600'	53·5"	...	...	...	...	..	...	
	Mandla	22° 30'—22'	80°—81°	1,800'—3,016'	55"	...	...	...	...	...	...	
	Balaghat	22° 20'—22°	80° 30'—81°	1,500'—2,954'	60"	0·29	0·33	0·32	0·38	0·35	0·33	
	Bilaspur	22° 20'—22°	82° 30'—82° 43'	800'—3,400'	48·85"	...	...	...	...	...	...	
	Raipur	21° 25'—20° 2'	81° 48'—82° 35'	1,100'—2,000'	50	...	...	...	...	...	...	

Two facts appear to stand out very clearly—primarily, the influence of elevation above Mean Sea level ; and, secondarily, the effect of rainfall. Within the geographical limits of its distribution, statistics would appear to show that, everything else being equal, the mean annual girth increment of Sal will fall with every rise above an altitude of 600 feet above Mean Sea level, and correspondingly increase with every rise in the mean annual rainfall above 50 inches :—

Forest Division.	Mean annual Rainfall. Inches.	Elevation above Mean Sea level Feet.	Mean annual Girth increment, for Sal trees 6 feet girth. Inches.
Pilibhit, United Provinces . .	55	630	0·64
Kheri, United Provinces . .	47·6	480—620	0·70
Darjeeling, Bengal . .	175	620—4000	0·71
Kurseong, Bengal .	145	431—1900	1·03
Jalpaiguri, Eastern Bengal .	123·20	300—400	0·73

More data are however required, and these are now being collected, to show the exact height above Mean Sea level and the approximate rainfall of each sample plot ; as well as soil and sylvicultural treatment.

Turning now to the effect of the sylvicultural treatment on the development of the annual girth increment, considerable difference naturally occurs in the rate of girth growth of partially suppressed and dominant trees, a fact which should be clearly borne in mind in taking the measurements of type trees in sample plots. The following statement gives the results obtained in the few cases in which the measurements of the two classes of trees have been separately recorded :—

Name of Sal Reserve.	Mean annual Girth increment.	
	Dominant trees.	Partially suppressed trees.
Garhwal, United Provinces	0·530	0·353
Kurseong, Bengal	0·90	0·58
Jalpaiguri, Eastern Bengal	0 899	0·405

In approximately even-aged Sal woods, thinnings also have a very marked influence on the rate of girth growth, a question which will be further considered under the head of "Thinnings" (Part IV, Section 7).*

Name of Forest Reserve.	Mean annual Girth increment in inches of 6-foot Sal trees.		
	Not thinned.	Lightly thinned.	Heavily thinned.
Saharanpur, United Provinces . .	0·46	0·72	
Ganges Division, United Provinces .	0·35	0·46	
Garhwal " " " . .	0·38	0·66	
Kumaun " " " . .	0·31	0·44	
Pilibhit " " " . .	0·61	0·76	

Coppice Shoots.

The development of the girth of coppice shoots in Sal forests under systematic coppice treatment requires to be taken in hand : the subject having so far been greatly neglected. The following statement summarises the information at present available :—

Name of Division.	Name of Reserve.	Girth measurement in inches at breast height at the age of					
		4	8	12	16	20	24
Gonda Division, United Provinces.	Tikri Reserve.	...	...	...	..	16″	...
Jaunsar Division, United Provinces.	Kalsi Forest	..	..	...	14″	...	..

* See also Indian Forester, Vol. XXVII, page 583.—*The effect of thinnings in Sal Woods, by F. B. Dickinson.*

SECTION 4.—SHAPE OF STEM.

Laws which govern the development of the shape of the stem of single trees in general :—

I.—The shape of the stem depends on the total height increment, and on the growth of the diameter at all heights, both these factors being to a certain extent proportionate to the space allotted to the tree for the development of its crown.

II.—In a tree which has grown in a crowded wood, the thickest layers of new wood are at the top of the trunk, just below the new branches : and these annual layers of wood get thinner towards the foot of the tree, until a certain age.

III.—As the tree ages, the annual rings begin to get broader at the butt, producing a swelling which extends to varying heights, 4 to 12 feet from the ground, according to the age of the tree and the growing space.

IV.—The more favourable the locality, the more satisfactory the density of the crop, that is, the better the height growth, the greater will be the thickness of the annual layers formed near the top of the stem.

V.—In trees grown in the open the annual layers are either of equal thickness throughout the length of the stem, or diminish from top to bottom.

VI.—Any change of state affecting the conditions under which a tree is growing will cause it henceforth to assume the form characteristic of its altered environments. Thus, the standards retained after the exploitation of the surrounding coppice will soon tend to assume the characteristic conical shape of isolated trees.

VII.—It follows that whenever it may be required to compare the cubic contents of a tree before and after its isolation, it will be necessary not only to take account of the increase in girth at breast-height : but also of the change which may have occurred in the shape of the stem throughout its length.

The outlines of typical Sal stems, at various periods of their development, and for trees grown under definite conditions are best indicated by a graphic representation of a cross section of the stem (Figure 2) : but sufficient data are not at present available to lead to any definite conclusions.

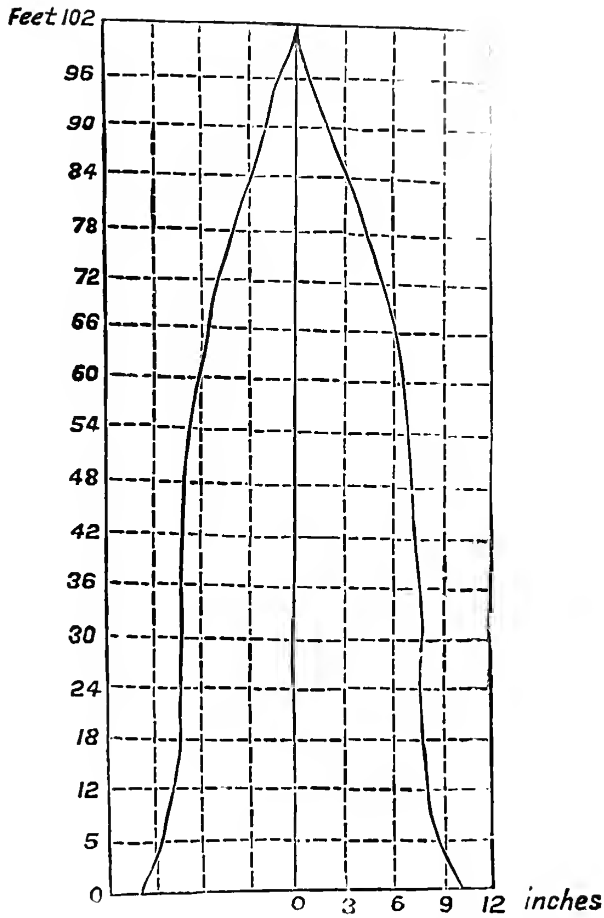

Figure 2. Longitudinal section of a Sal tree in an even-aged crop, United Provinces.

Section 5.—Volume Increment.

Laws which govern the volume growth of single trees in general :—

I.—The volume increment of a seedling is very slow at the commencement of its life ; but it increases continuously year by year, fairly fast in some species, slower in others in many cases even until the tree reaches complete maturity. As a rule, however, the annual volume increment reaches a maximum about the time the height growth ceases, and thereafter remains constant.

II.—The average annual increment does not as a rule culminate before the usual age of exploitation has been reached, but this depends on species.

III.—The growing space allotted to a tree is the chief factor influencing the rate of volume increment; the more crowded the wood, the slower the volume increment. A tree grown in a close crop will at once respond by increased volume increment to any enlargement of the growing space allotted to it.

IV.—The volume increment of standards reserved in a wood treated under the system of coppice with standards differs from that of similar trees grown in crowded woods. The volume increment of standards is said to increase appreciably in the year immediately following the exploitation of the surrounding coppice.*

Data indicating the progress of the growth in volume of Sal trees are not at present forthcoming; and the absence of distinct annual rings renders the immediate solution of this problem a matter of some difficulty. Indeed, existing conditions would point to the fact that the elaboration of tables of co-efficients (stem form factors), and the preparation of stem volume tables should alone for the present engage the attention of Forest Officers. These subjects are dealt with in the Sections immediately following.

SECTION 6.—STEM FORM FACTORS.

Form factors are used primarily to determine the volume of trees. They undoubtedly also help to indicate the shape of a stem: but stems having similar form factors need not necessarily have the same shape; and conversely, if so called artificial form factors be used, trees having the same shape but differing in height will not have the same form factors.

Stem form factors may be prepared from diameter measurements taken at any height from the ground. European Forest Research Bureaux have, however, agreed to measure all trees at breast-height (1·3 metres); and these so called "*artificial*" form factors are the only ones now used. Form factors vary with the height of the tree, and unless the greatest accuracy is required it is unnecessary to take into consideration either age or quality of locality: though in Germany a distinction is usually made between young, middle-aged, and old trees. It has been found that form factors for particular species prepared for a definite tract are applicable to widely separated districts.

It is hoped that the collection of data, which will lead to the preparation of stem form-factor tables, will be taken in hand at an early date.

The following form of table may be found convenient for the purpose of recording results obtained :—

* In the Koderma Reserve of the Palamau Division, and in the Bhagatpoli Reserve of the Sambalpur Division, Bengal, sample plots have been established to test the rate of growth of Sal standards after coppice fellings: but figures are not at present available.

Sal Stem Form-Factors.

(Diameter measured at height of 4″ 3′ from ground.)

Height in Feet.	Stem Form-Factors.			
	For young trees. 21—40 years.	For middle-aged trees. 1—80 years.	For old trees. 81 years and over.	For trees of all ages.
20	For timber only, or Timber and Firewood.			
25				
30				
35				
40				
45				
50				
55				
60				
65				
70				
75				
80				
85				
90				
95				
100				
105				
110				
115				
120				

Stem Form Factors result when the volume of the stem alone, including the top, is used in the formula ; whilst *tree form-factors* relate to the entire volume of the tree, including branches, twigs and all. In addition, for use in commercial estimating, *timber* and *merchantable* form factors may be prepared. The former usually result from a theoretical definition of timber, a minimum diameter measurement being prescribed for research purposes : the latter, or merchantable form factors, must be prepared separately for different localities and they depend on the minimum size of timber which can be disposed of in the local market. Timber and merchantable form factors are dealt with in Part III of this Note.

The following form of table has been suggested by Henry Solon Graves in his " Forest Mensuration "* :—

Diameter, breast-height in inches.	Height in feet.			
	40	45	50	55
	Average Merchantable Form Factors.			
6 Inches . .				
7 " . .				
8 " . .				

Section 7.—Stem Volume Tables.

Stem Volume Tables may be prepared either in terms of diameter and height, or merely in terms of the diameter only. Such tables should as a rule be prepared separately for circumscribed tracts. In Germany age is also taken into consideration, a minuteness of research, which in reality only appears necessary when it is sought to make volume tables applicable to vast regions, or when they are specially required to accurately determine the volume of the different age-classes of a systematically worked forest.

Volume tables are nowadays less used than form factors, as the latter are more handy. Nevertheless, in India, under existing conditions

* Forest Mensuration by Henry Solon Graves, M.A., Director of the Forest School, Yale University, New York. John Wiley and Sons, 1906.

volume tables in terms of the diameter, though less accurate, would probably more nearly meet present requirements.

The following forms of volume tables may be found useful : the one, in terms of the diameter alone ; the other, in terms of diameter and height.

Volume Tables for Sal.

I.

Diameter at breast-height.	Volume of timber.	Diameter at breast-height.	Volume of timber.
Inches.	Cubic feet.	Inches.	Cubic feet.
12		24	
15		27	
18		30	
21			

II.

Total height.	Diameter over bark at breast-height in inches.						
	12	15	18	21	24	27	30
20 feet . .							
30 " . .							
40 " . .							
60 " . .							
80 " . .							
90 " . .							
100 " . .							
110 " . .							
120 . . .							

Besides *stem volume tables*, volume tables may also be prepared for trees of different diameters and merchantable lengths of timber ; or for trees grouped by diameter and number of logs ; or for trees of different diameters and tree-classes. In addition, tables may be prepared showing the ratio of merchantable to total contents, so that the volume of merchantable timber may be obtained by the use of the ordinary stem volume tables. The preparation of *graded volume tables*, showing the amount of timber of different grades for trees of different sizes has also been suggested : such tables enable the determination of the money value of standing trees better than the ordinary volume tables.*

SECTION 8.—VOLUME INCREMENT PER CENT.

Laws governing development of volume increment per cent. of single trees in general :—

I.—The volume increment per cent. is very high during very early youth ; subsequently it steadily decreases, though slower and slower, until the death of the tree.

II.—All the factors which influence the volume increment equally affect the volume increment per cent. : the closer the crop, the lower the increment per cent. ; whilst any change of state affecting the growing space allotted to the tree will entail a corresponding change in its increment per cent., so much so. that the latter may temporarily increase three-fold as the result of judicious thinnings in over-crowded woods.

In calculating the volume increment per cent. in order to avoid errors due to years of exceptional growth, the increment is taken for a series of years, generally 5 to 10 years. † The volume increment per cent. is chiefly used for the purpose of testing the activity of the capital invested in forestry, and in predicting future growth of a tree or wood : but no statistical data are at present available from which such tables could be prepared for the Sal in India.

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* See " Forest Mensuration " by Henry Solon Graves.

†In calculating the Volume Increment per cent., Pressler's formula may be employed, *viz* :—

$$\text{Increment per cent.} = \frac{V - v}{V + v} \times \frac{200}{n}$$

See Schlich's Manual of Forestry, Vol. III, page 185.

Part III.

THE DEVELOPMENT OF THE DIFFERENT PARTS OF A SAL TREE.

1.—The Stem (Timber, Firewood, Merchantable Timber).
2.—The Crown.
3.—The Bark.
4.—The Roots.

PART III.

STEM (TIMBER, FIREWOOD, AND MERCHANTABLE TIMBER): CROWN: BARK: ROOTS.

Section 1.—Preliminary Matters.

A Sal tree consists of a crown, root and stem. The stem is the most important part of the tree, and the available statistical data relating to the progress of its growth in volume have already been dealt with in Part II. From a commercial point of view, however, a stem may be said to consist of timber or merchantable timber (wood above a certain minimum girth), and firewood (small wood below a certain girth). The development of the timber and the firewood of a stem and the proportion which each of these, as well as the roots and crown, bear to the total volume of the stem is of importance in forest management; and data dealing with these points have in recent years been collected and published by the several Forest Research Bureaux of Europe.

Section 2.—The Development of the Timber, Merchantable Timber, and Firewood in Stem.

Laws which govern development of timber and firewood in general:—

I. For a single tree, the proportion between the volume of firewood and the total volume of the stem continues to diminish rapidly in early youth with every increase in diameter until it becomes constant.

II. For trees of equal diameter, the taller the tree, the smaller the proportion of firewood.

III. For trees of equal height, the proportion of firewood increases slightly with the diameter.

IV. Trees grown in very open woods produce a proportionately larger quantity of small wood than those grown in close crops.

V. In a whole wood, the volume of the small wood during early youth increases rapidly year by year; it soon, however, reaches a maximum; then diminishes slightly for some years until it eventually remains constant.

VI. The current and the mean annual volume increment of the timber alone in a tree or wood culminates at a much later date than that of the whole tree or wood.

VII. The greater the girth dimension of the timber, the later will the volume increment culminate, and the higher will have to be the rotation of the greatest production of volume.

VIII. The volume increment per cent. for the timber alone of a tree or wood is higher than that calculated for the whole tree or wood at any given age: but the difference continually decreases as the tree increases in age.

The exact size of diameter separating the timber of a stem and especially the merchantable timber from the small wood or firewood will vary in different localities according to the different requirements of the market : but for statistical purposes it is essential that a definition of universal applicability be accepted for timber, and it is suggested that this be fixed for India at 6 inches diameter or 18 inches girth* : the definition of "merchantable timber" necessarily varying in each locality.

The merchantable timber obtained from a tree or wood at different ages is usually graded into various classes which may vary indefinitely according to market requirements from one locality to another. In India few descriptions of fashioned Sal timber are exported from the Government reserves ; the stem being either made into rough-squared logs of convenient lengths, or sawn into sleepers or scantlings. Data giving for various localities the average outturn in cubic feet of rough-squared logs, planks, or sleepers, for trees of different girth classes have not been systematically collected ; and only a few unreliable figures are at present available.

In the Garhwal Forest Division, United Provinces, 3,238 Sal trees, 2 to $2\frac{1}{2}$ feet in diameter, measured by Mr. Dansey, yielded the following lengths of timber :—

Sal.

Number of trees measured. (2′ to 2′ 6″ diameter.)	Length of merchantable timber† per tree.
218 trees.	10 feet.
353 "	15 "
729 "	20 "
787 "	25 "
729 "	30 "
253 "	35 "
125 "	40 "
39 "	45 "
5 "	50 "
3,238 trees measured.	Average length of merchantable timber, $24\frac{1}{2}$ feet.

*For statistical purposes, all Forest Research Institutes of Europe have agreed to take a girth of 2 decimeters (=7·874 inches) as separating timber (Derbholz or Bois fort) from small wood or firewood (Reisholz or Menu bois, ramiers).

†Exact definition of "merchantable timber" not available.

The following tables give the average volume of workable sound timber in the log obtained from Sal trees of various girths in the Trans-Sarda forests of the Kheri Division, United Provinces; and in the Tista Range of the Tista Division, Bengal.

VOLUME OF DRESSED LOGS.

*Trans-Sarda Forests, United Provinces.**

Girth of standing tree (at breast-height.	Volume of dressed logs in cubic feet.		
	Length 0 to 30′.	Length 30′ to 60′.	Total.
8 3″	77·2	43·8	121·0
7 6″	65·6	38·0	103·6
6 9″	55·0	32·6	87·6
6 0″	45·3	27·6	72·9
5 3″	36·6	23·0	59·6

VOLUME OF WORKABLE SOUND TIMBER IN THE LOG.

Tista Range, Tista Division, Bengal.†

Girth at 4′ from ground.	Cubic feet (average).
7 feet to 9 feet	121
9 ,, ,, 11 ,, ...	178
12 ,, ,, 14 ,, ...	227

In the Goalpara Division of Assam, 100 Sal trees, with a girth of 5′ 7″ at breast-height, taken at random and measured for the purpose, gave an average outturn per tree of 39·67 cubic feet of merchantable timber roughly squared. Approximately the same result was also obtained in the Banjar Valley Reserve, Central Provinces, from the measurement of 6,954 Sal trees (sound and partly unsound), 6 feet in girth: 6,954 trees, 6 feet in girth, yielding 256,630 cubic feet of merchantable timber.‡

*Figures calculated by Mr. F. A. Leete, I.F.S.

†Appendix C, Working-Plan for the forests of the Tista Division by H. D. D. French, I. F. S.

‡Mr. R. Thompson, Divisional Forest Officer, Mandla, reports that from measurements taken in the Banjar Valley reserve, a 6-foot Sal tree will yield an average of 30 narrow gauge or 10 broad gauge sleepers; a Sal tree with a mean girth of 5′ 3″ yielding 15 narrow gauge or 5 broad gauge sleepers.

Figures are not at present available showing either the quantity of small wood (firewood) which may be expected from Sal trees of different girths, or the proportion of small wood to timber. The following table gives the results of experiments carried out by Mr. H. H. Haines, I.F.S., to determine the average outturn in cubic feet solid of Sal trees of different mean girths in the Jalpaiguri Reserves, Eastern Bengal.

JALPAIGURI DIVISION, EASTERN BENGAL.

Determination of factors for the conversion of trees into cubic feet.

Species.	Diameter Class.	Number of trees measured.	Average girth in inches.	Average height in feet.	NUMBER OF CUBIC FEET FUEL.		Number of cubic feet Timber.	Total Number of cubic feet Solid.	Average cubic feet Solid per tree.	REMARKS.
					Stacked.	Solid.				
1	2	3	4	5	6	7	8	9	10	11
Sal .	3″–9″	101	18·00	40	843	481·71	...	481·71	4·77	Co-efficient used = 4/7.
,, .	9″—15″	68	37·63	63	2198·24	1256·13	785	2041·13	30·01	
,,	15″—21″	20	55·35	70	1636·20	933·54	546	1479·54	73·98	
,, .	15″—18″	31	51·60	70	2064	1179·43	710	1889·43	60·95	
,, .	18″ 21″	19	58·80	83	1330	760·00	665	1425·00	75·00	

Volume of split wood.—The timber and the small wood yielded by Sal trees of different girths is sometimes split and stacked to form firewood. Data are then required to show the average outturn in stacked cubic feet that may be expected in each case. In addition, in order to convert the stacked volume into solid cubic contents, separate co-efficients must be used both for the stacks obtained from the split timber and for those formed of the small wood. No such co-efficients are at present available.

In the Lansdowne Range forests of the Ganges Division, United Provinces, Sal trees (lowest quality of locality) 3′ 4′ in girth are said to yield an average of 45 stacked cubic feet of fuel. Again, in the Bhira Range forests of the Kheri Division, United Provinces, 400 stacked cubic feet of six-months dried split Sal fuel are considered to be equivalent to 200 solid cubic feet (co-efficient 0·5), and to 100 maunds of firewood.*

*1 maund = $82\frac{1}{2}$ lbs. Mr. P. H. Clutterbuck, I.F.S., writes :—"The formula 4 stacked cubic feet = 2 cubic feet solid = 1 maund or $82\frac{1}{2}$ lbs. was arrived at after a great deal of experiment in the days when large quantities of fuel were being supplied to the Railway. The above formula represents measurements taken after 6 months' seasoning."

Section 3.—Development of the Crown.

Rules which govern the development of the crown of trees in general :—

I. The proportion of the crown to the total volume of at ree varies very considerably with the age of the tree, and the conditions under which it has grown.

II. For equal heights and equal girths, old trees have proportionately smaller crowns than young trees.

III. For equal girths, the proportion of branch wood diminishes with the height; whilst for equal heights, the proportion of branch wood increases with the diameter.

IV. The volume of the crown may be taken as equal to 60, 30 or 15 per cent. of the volume of the stem, according as to whether the length of clear bole is one-quarter, one-half, or three-quarters of the total height of the tree.*

The proportion of branch wood in a tree grown in a crowded wood, calculated for trees of different heights may be expressed either in terms of the total volume of the tree, or of the length of clear bole; but so far no data are available for the Sal.

Section 4.—Development of the Bark.

Laws which govern the development of the bark of trees in general:—

I. The greater the diameter of the stem, the older the tree, the poorer the quality of the locality, the more isolated the tree: the thicker the bark.

II. The bark is thicker at the base of the trunk than at the extremities.

III. The growth in thickness of the bark is extremely slow as compared with the diameter increment of the stem; so that, as the stem increases in diameter, the ratio between volume of bark and total volume of tree diminishes.

Sal bark has not so far been exported to any extent; but, as a result of recent enquiries, it may attain value for tanning purposes. The preparation of yield tables, giving the weight, volume, or percentage of green and dried bark that may be expected from Sal trees of different girths will then become a matter of some importance.

The following table,† the result of the measurement of a large number of logs, gives the average thickness of bark to be found along the length of a well-shaped Sal stem :—

*Gesetz der Stammbildung. Pressler.

†Working-Plan for the Trans-Sarda forests by Mr. F. A. Leete, I.F.S.

Trans-Sarda forests, Kheri Division, United Provinces.

Girth of tree at breast-height 4′ 6″ from ground measured over bark.	Girth of tree at base 1′ 6″ above ground measured over bark.	Decrease in girth of dressed logs in inches owing to thickness of bark.					
		Base to 10′.	10′ to 20′.	20′ to 30′.	30′ to 40′.	40′ to 50′.	50′ to 60′.
7′ 6″ to 6′ 9″	7′ 8″ to 6′ 11″	8½	6½	5½	5	5¾	4½
6′ 9″ „ 6′ 0″	6′ 11″ „ 6′ 2″	7	5½	4¾	4½	4	3¾
6′ 0″ „ 5′ 3″	6′ 2″ „ 5′ 5″	5½	4½	4	3¾	3½	3¼
5′ 3″ „ 4′ 6″	5′ 5″ „ 4′ 8″	4½	4	3½	3¼	3	2¾

SECTION 5.—DEVELOPMENT OF THE ROOT.

The under-ground portion of a tree developes proportionately to the crown : but the stool does not in India, so far as the Sal is concerned, yield produce of any value, especially owing to the prohibitive cost of its exploitation. As a rule, when a tree is cut flush with the ground, the volume of the underground portion of a tree is found for most species to equal one-eighth to one-quarter of the total volume of the stem and crown* : but no data are available bearing specially on the Sal.

*According to Hüffel.

PART IV.

THE DEVELOPMENT OF THE STEM OF WHOLE SAL WOODS.

PART IV.

THE GROWTH OF THE STEM OF WHOLE WOODS.

Section 1.—Preliminary Matters.

In the following pages it is proposed to consider more particularly the development of even-aged woods, produced directly from seed, either naturally or artificially by sowing or by planting. In such a wood, fully stocked, a struggle for existence will very soon arise between the individual members of the crop. In rare cases, with certain species, more particularly in abandoned artificial plantations, the struggle may become so prolonged, without any of the individuals obtaining a decided advantage, that the crowns become deficient, the crop ceases to grow, and eventually loses all power of re-establishing itself. But in the majority of cases, certain individuals soon take the lead, whilst others lag behind, probably to die : so that the crop consists of trees in all stages of development—dominated, dead and dying, and dominant.

It will, however, be found that each individual of a crop may be brought into one or other of the following five classes, in accordance with G. Kraft's classification, which is the one now adopted by all the European Forest Research Institutes, namely :—

Class I.—Predominant : trees with an exceptionally vigorous crown.

Class II.—Dominant : trees with a well developed crown.

Class III.—Slightly dominant : trees with a poorly developed crown.

Class IV.—Slightly suppressed : trees with an incomplete crown.

Class V.—Wholly suppressed : trees with the crown wholly below the level of the dominant trees.

As soon as a tree passes into the 4th or 5th class, as soon as its crown loses its shape and becomes attenuated, it can no longer be said to form part of the growing wood ; it merely becomes so much exploitable material. Thus, the first three classes of dominant trees are said to form the major or primary part of the growing stock, whilst the remaining two classes form the minor or secondary part of Wood, or Intermediate Yield.

As a direct result of this struggle for existence, causing year by year a decrease in the number of stems per unit of area, it is evident that the progress of the volume increment of a whole wood differs altogether

from that of a single tree both as regards increment in height and diameter, basal area and volume ; and it is impossible to deduce the progress of the volume increment of a whole wood from that of a single tree in the crop. In a whole wood, in the struggle for existence, the least vigorous stems disappear : what is now the mean tree of a crop must formerly have been a dominant tree. Consequently both the mean height and the mean diameter of a crop increases more quickly than that of the individual trees. Again, when a tree passes into the "*Minor Part*" of the wood (intermediate class), the basal area and the volume of the Principal or "*Major Part*" of wood is reduced by that amount. Consequently the total or Final Yield of a whole wood at any given age is equal to the volume of the wood at that age plus all intermediate yields previously exploited.

The collection of data relating to the development of whole woods is of the greatest practical utility to the forester, since it leads to the preparation of *Yield Tables*, which are indispensable in the systematic working of forests, besides indicating, sufficiently accurately, the normal growing stock corresponding to a given quality of locality and rotation. Yield Tables may either be prepared for a particular district of limited extent, or for a whole province or country : but *local* Yield Tables are undoubtedly to be preferred. The Forest Research Bureaux of Europe have agreed to show in each Yield Table the development of normal woods of five different quality classes, namely :—

Class	I.—Best	Quality	Locality.
,,	II.—Good	,,	,,
,,	III.—Medium	,,	,,
,,	IV.—Mediocre	,,	,,
,,	V.—Inferior	,,	,,

The quality class to which a wood belongs is indicated by its cubic contents at the age of 100 years.* Thus a normal Scotch Pine wood, 100 years of age, yielding a volume of 7,500 cubic feet per acre or over would belong to the first class ; one yielding 6,000 cubic feet per acre falls into the second class ; and so on.

In making use of *Yield Tables* considerable difficulty is sometimes experienced in determining the quality class to which a particular wood, whose future development it may be required to ascertain, belongs. Considerable divergence of opinion exists as to the particular index to be accepted ; the locality (soil and climate), the height growth, the diameter increment, the basal area, and the volume of the wood have each been

*According to the decision accepted by the Forest Research Bureaux of Germany at a Forest Conference held at Ulm in 1888.

advocated ; and it is likely that the last will yield a more correct indication.* Pending a solution of the question, Yield Tables, as at present prepared, show per unit of area the number of stems, the mean height and diameter, the basal area and the volume of normal woods of different ages according to quality classes ; and statistical data relating to each of these factors must be collected.

Turning now to the species under investigation it must at once be noted that no such tables can at present be prepared for the Sal in India, since the absence of even-aged woods, and the wholly abnormal condition of the majority of the Sal woods under systematic management renders the collection of sufficient statistical data impossible. Nevertheless it is probable that in certain Divisions a beginning can be made in studying some of the factors which find a place in the Yield Table.

In the United States of America, so-called Yield Tables are prepared for uneven-aged woods to show the future yield of many-aged stands at different periods after a portion of the trees have been cut under a specified method of selection. In other words, the tables under consideration contain the merchantable yield per acre of a given species before the selection cuttings, and the predicted future yield in 10, 20, and 30 years after cutting : the tables being based on the assumption that the timber will be cut to a specified diameter limit.† Such tables depend wholly on the correct calculation of the percentage of stems that are likely to survive to pass from one girth class to the next ; on the rate of girth or diameter increment ; and on the volume of the mean tree of each girth class—questions which are dealt with in different parts of this Note .

SECTION 2.—NUMBER OF STEMS PER ACRE.

Laws which govern the development of the density of stems in even-aged woods in general :—

I. At an early age in crowded woods, the number of stems per acre decreases very rapidly year by year.

II. The rate of diminution, which is faster in favourable localities, decreases as the wood ages : but never ceases as long as the trees continue to grow.

III. In mountain forests, the number of stems per acre increases with elevation above sea level.‡

The number of stems per acre is liable to greater and more arbitrary variations than any other factor connected with the development of

* See also Schlich's Manual ; Vol. III, page 97.

† Forest Mensuration by Henry Solon Graves. The method is similar to that usually employed in India for estimating the yield of selection-worked Sal and Teak forests.

‡ Der forstliche Versuchswesen, Ganghofer. See also Indian Forester, Vol. XIX, page 6.

whole woods. Moreover, the number may vary without appreciably affecting the basal area and volume of the whole wood. The determination of the average number of stems per acre, corresponding to different ages, is of importance to the forester, particularly in connection with the preparation of Yield Tables: but owing to the restricted number of even-aged Sal woods the early collection of data bearing on this question becomes difficult.

In the case of uneven-aged woods, woods treated under the selection system, the determination of the normal proportion which should exist between the number of stems of the different age or diameter classes, and the percentage of trees in any class that may survive to pass into the higher class is of importance; and the periodical enumeration of the growing stock in sample plots or compartments with this object in view has been duly prescribed. But data are not as yet available. A suggestion has been made that the areas covered by the crowns of the average trees in each class should be measured, in order to arrive at the number of trees of each class that can stand on an acre. Such procedure is not likely to yield useful data, and the direct observation and measurements of small groups of trees will in all probability be found more satisfactory.

Owing to the abnormal condition of many of the Sal forests under systematic working, complete or partial enumerations of the stock have not as a rule been carried out at the time of the preparation of Working-Plans, the yield being prescribed by area. The following table, however, shows the average number of Sal stems of each girth class per acre to be found in those forests which have been enumerated :—

Name of Province.	Name of Division.	Name of Forest.	NUMBER OF TREES PER ACRE IN EACH GIRTH CLASS. I Over 6′	II 4½′—6′	III 3′—4½′	IV 1½′—3′	V 0′—1½′	REMARKS.
			With a 6-foot girth cutting limit.					
United Provinces.	Ganges .	Ganges . .	2·91	7·67	*	*		* Not counted
	Siwalik .	Thano . .	0·30	3·70	21·10	65·00	*	
	Garhwal .	Raher Garibul-chand.	0·70	2·70	17·00	56·90	*	
	Kumaun .	Kumaun . .	1·60	3·49	*	*	*	
	Kheri .	Trans-Sarda .	2·94	6·98	10·17	18·90	209·11	
	Bahraich .	Bhinga . .	1·14	1·47	3·51	14·51	*	
	Average for the United Provinces.		1·59	4·34	12·95	38·84	...	
Bengal .	Puri . .	Puri . .	0·3	1·33	9·96	*	*	
	Kurseong .	Kurseong . .	0·64	5·17	15·55	27·02	*	
	Average for Bengal . .		0·47	3·28	12·76	27·02	...	
Eastern Bengal and Assam.	Garo Hills .	Dambu . .	2·19	2·32	3·33	7·80	*	
	” ” .	Darugiri . .	2·54	5·07	7·86	11·87	20·60	
	Buxa .	Buxa . .	0·55	3·34	6·77	8·20	*	
	Average for Eastern Bengal and Assam.		1·76	3·58	5·99	9·29	...	
	Average for all Sal forests enumerated.		1·27	3·73	10·57	25·05	...	
	Percentage per girth class .		3·1	9·2	26·0	61·7	...	

Mr. F. A. Leete, I.F.S., has calculated that the normal stock per acre in a pure Sal forest under the selection system with a 6-foot cutting limit should be :—

Class	6′ and over	4½′—6′	3′—4½′
Number of stems per acre .	13	16	21

He assumes that 75 per cent. of the stems of Class III will survive to pass into Class II, 80 per cent. of Class II will pass into Class I, and 90 per cent. of Class I will be available for felling. If the above estimate be accepted as approximately correct the present abnormal condition of the Government Sal reserves as regards the higher girth classes will be apparent :—

Class	6′ and over	4½′—6′	3′—4½′
Number of stems per acre .	1·3	3·7	10·6

The latter figures do not however, in every case make full allowance for the proportion of the area occupied by stems of miscellaneous species other than Sal.

SECTION 3.—HEIGHT INCREMENT OF WHOLE WOODS.

Laws which govern the height development of whole woods in general :—

I. The laws which govern the height development of whole woods and of single trees are analogous : though the two do not progress in exactly the same manner.

II. The annual height increment during earliest youth is comparatively slow, it then increases fairly rapidly, remains constant for a time, then decreases and ceases altogether or nearly so.

III. The greater the annual height increment at the commencement, the sooner will it culminate.

The increase in height of each and every tree, added to the continual elimination of the shorter individuals tends to raise the mean height of the whole wood : but no data are at present available showing the progress of the average height growth of an even-aged Sal seedling forest : neither is their collection at present possible.

The same difficulty does not however arise in the case of coppice areas under systematic working, and the solution of this problem should now receive attention. In the Nawabganj forest of the Gonda Division, United Provinces, Sal coppice shoots in an even-aged coppice wood 20 years of age are said to attain an average height of 30 feet.

The following diagram (Fig. 3) exhibits the development in height of a coppice wood in the Tikri Working Circle, Gonda Division, United Provinces, from data supplied by Mr. Gulab Rai, Provincial Forest Service.

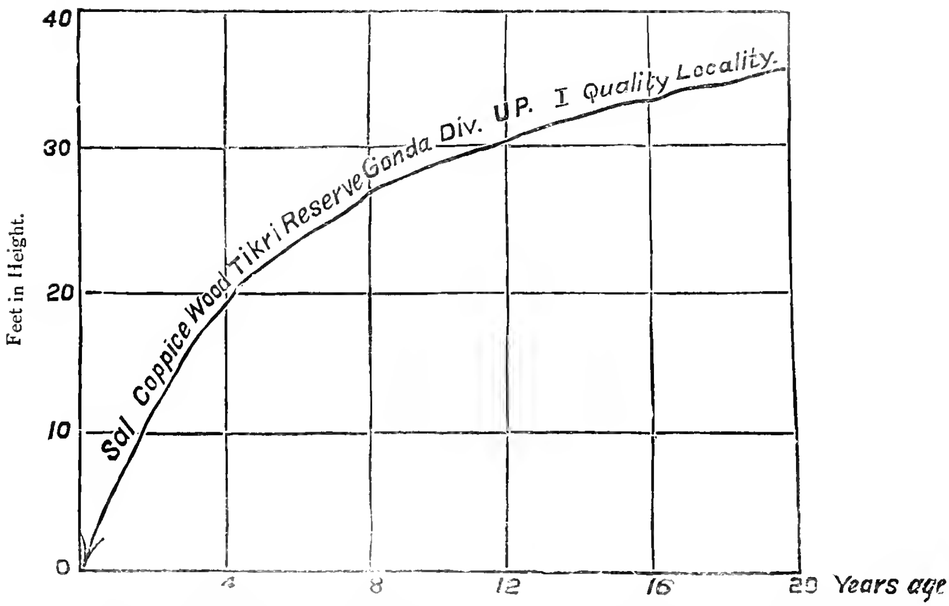

Fig. 3. Development in mean height of a Sal coppice wood, Tikri Reserve, Gonda Division, United Provinces.

SECTION 4.— DIAMETER INCREMENT OF WHOLE WOODS.

Laws which govern the diameter development of whole woods in general :—

I. In even-aged woods considerable difference will always exist between the diameter of the different individuals constituting the crop : the fewer the number of stems per acre and the older the crop the greater the difference.

II. With the above exception, the development of the mean diameter of a whole crop differs from that of a single tree in exactly the same manner as the mean height of a whole wood differs from that of a single tree.

Data relating to the development of the diameter of Sal in whole woods are not available.

The mean diameter of the shoots of an even-aged coppice wood, 20 years of age, situated in the Nawabganj Forest, United Provinces, a poor quality of locality owing to insignificant depth of soil, was found to be 8 inches.

The following table shows the development of the girth of a coppice wood in the Tikri Working Circle of the Gonda Division, United Provinces, and in the Kalsi Coppice of the Jaunsar Forest Division, United Provinces :—

	Age of coppice in years.				
	4	8	12	16	20
	Mean girth at breast-height in inches.				
	Inches.	Inches.	Inches.	Inches.	Inches.
Tikri Forest, Gonda Division, United Provinces.	9·7	12·0	14·1	...	16·0
Kalsi Forest, Jaunsar Division, United Provinces.	7·5	...	...	14·2	...

The percentage of stems of different diameter classes to be found in an even-aged unthinned Sal wood, grown under average conditions of a given age, may best be exhibited by means of a diagram :—

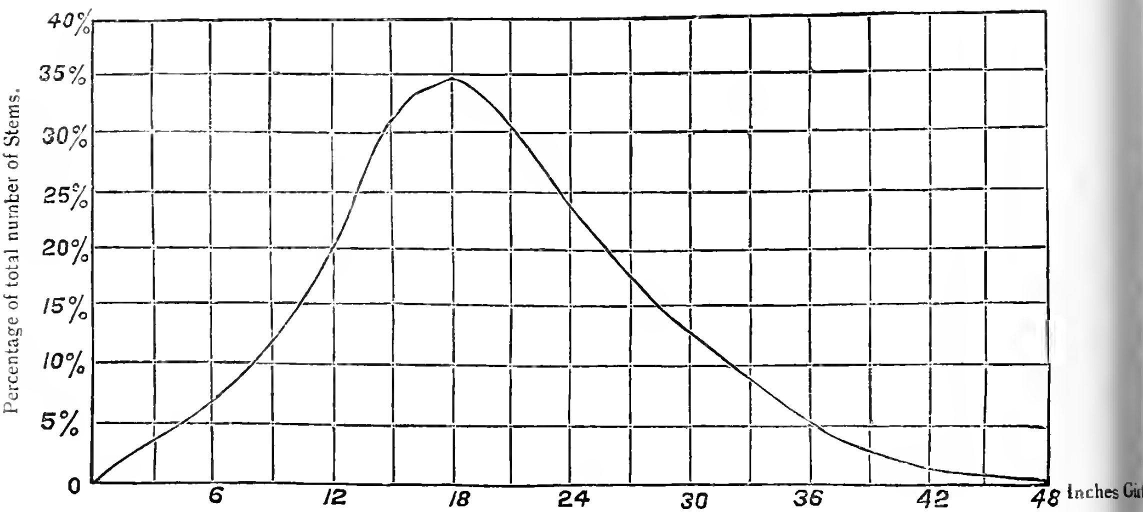

Fig. 4. Percentage of Sal stems of different girths in an even-aged wood, 50 years of age. (Age estimated).

The following table relating to coppice shoots has been prepared by Mr. F. F. R. Channer, I.F.S., from data collected by him in the Ekauna Forest of the Bahraich Division, United Provinces :—

Girth measured at breast-height.							
Girth under 1′	1′—1½′	1½′—2′	2′—2½′	2½′—3′	3′—3½′	3½′	Remarks.
Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	
26	35	25	11	3	...	...	Coppice growth 20 years old.
36	15	18	17	8	5	1	Coppice growth 30 years old.

Percentage of Sal shoots of different girths in an even-aged Sal coppice 20 and 30 years of age, respectively.

SECTION 5.—BASAL AREA INCREMENT.

Laws which govern the basal area development of whole woods in general :—

I. The total basal area of a whole wood is very small at the commencement: but it increases continuously during the whole period of the crop's existence.

II. The basal area increment depends largely on the growing space necessary for the proper development of the species, and on the quality of the locality.

III. The greater the growing space required, and the poorer the locality (notwithstanding the larger number of stems) the sooner will the basal area increment begin to decrease.

The basal area of a whole wood is equal to the sum of the basal areas at breast-height of the several individuals constituting the crop. But, since the number of stems per acre may vary without appreciably affecting the basal area of the whole wood, it follows that the latter is not proportionate to the number of stems per acre. Nevertheless, other factors being equal, the greater the number of stems, the greater the basal area of the whole wood. Data specially relating to the Sal are not, however, available.

SECTION 6.—VOLUME INCREMENT.

Laws which govern the development of volume increment of whole woods in general :—

I. The *total volume* of a whole wood is very small during early youth, and it increases slowly. Towards middle age it begins to rise very rapidly; but later on the annual increment steadily continues to fall until the death of the wood, without however ceasing altogether, except through disturbing factors.

II. The *current annual increment* of a whole wood rises rapidly after the first youth is passed, and as a rule culminates towards middle age (50 to 100 years), or even later, except in very favourable localities and in fast growing species when it may culminate at a very early age (between 30 and 40). After reaching its maximum the current annual increment falls, rapidly under favourable conditions, slowly in poor localities.

III. The *mean annual increment* of a whole wood keeps below the current annual increment until the two become equal: it then culminates, and thereafter slowly falls, though remaining greater than the current annual increment.

IV.—The progress of the *volume increment per cent.* for a whole wood is analogous to that of a single tree. It is very high during the early youth of the wood; it then diminishes very rapidy; and subsequently more slowly until absolute maturity is reached. The volume increment per cent. appears to vary only slightly between species.

The age at which the mean annual volume increment of a whole wood culminates is of great importance as indicating the rotation of greatest production of volume : but data are not available for the Sal, and owing to the absence of even-aged woods, the problem as far as it relates to seedling forests must for the present await solution.

For woods under regular coppice treatment figures might no doubt be collected within a short period of time : a question which is now receiving attention.

In the Nawabganj forest of the Gonda Division, coppice woods 19 years of age were found to yield an average of 550 cubic feet per acre after retaining 60 shoots to the acre : average size of shoots being 6 inches in diameter.

SECTION 7.—THINNINGS.

Thinnings, according to their intensity, have a very great influence on the development of the volume of whole woods.* The question is still under investigation in Europe, and only a limited number of data are available. It has been shown that in open woods, height increment is greater than in crowded woods ; but it decreases at an earlier age and the trees are more apt to develop low side branches. Heavy thinnings are not therefore advisable before the time when a suitable length of bole has been formed. Thinnings again (see table below), have a very decided influence on the development of the diameter, which so largely affects the value of a tree, whilst their effect on the volume of a crop appears to depend chiefly on species and age. It has been proved in Europe that judicious thinnings may cause the volume increment per cent. to increase by as much as 25 per cent. to 100 per cent. As a result the age at which the volume increment culminates may be raised, permitting of the adoption of a higher rotation without any loss in the final major yield : but data showing the effect of thinnings on the volume increment per cent. of Sal are not available in India.

The total yield of a crop at any age consists of the final yield occurring in that year *plus* the volume of the intermediate cuttings or thinnings. The proportion between final and intermediate yields has not so far been ascertained for the Sal. Neither have data been collected to show the volume of the intermediate cuttings that may be expected from Sal woods at different ages, or the percentage of final and intermediate yields for different rotations. The volume yield of the interme-

*Jacquot's "*Incendies en Forêt,*" pages 248 to 263, should be consulted. Also a series of articles by Emile Mer on "*L'influence de l'éclaircie des cépies sur la croissance des rejets,*" Eaux et Forêts, 1907, Nos. 11, 12, 13, 14.

diate cuttings is probably small at first ; it rises up to the age of 50 to 80, or a little longer ; culminates ; and then falls steadily to the end.

The following tables clearly exhibit the difference in the Mean Annual Girth Increment of Sal in thinned and unthinned sample plots, approximately even-aged :—*

(i) KUMAUN DIVISION.

Class.	KHONANI NORTH, 1 ACRE PLOT, THINNED, 13 YEARS.			SELANI, 1 ACRE PLOT, UNTHINNED, 13 YEARS.			REMARKS.
	No. of trees.	Average increase.	Time required to get through the class.	No. of trees.	Average increase.	Time required to get through the class.	
		Inches.			Inches.		
Sal IV 0′-1′ 6″	5	10·69	22 } 115	1	4·90	48 } 284	2,000′ elevation A. M. S. level.
„ III 1′ 6″-3	33	6·27	38	11	1·65	142	
„ II 3′-4′ 6″	21	4·28	55	32	2·49	94	
„ I 4′ 6″-6′	12	5·27	44	5	2·43	97	
„ IA above 6′.	...	...	...	...	...	...	
Total	71	...	159	49	...	381	

* See page 98, *ante*. Also Indian Forester, Vol. XXVII, page 583 : "A Note on the rate of growth of Sal in thinned and unthinned areas," by F. B. Dickinson Also see Indian Forester, Volume XI, page 558.

(i) KUMAUN DIVISION—*contd.*

Class.	LAKHMANMANDI, 17 YEARS. 2-acre plot, thinned. No. of trees.	Average increase.	Time required to get through the class.	½-acre plot, unthinned. No. of trees.	Average increase.	Time required to get through the class.	Remarks.
		Inches.			Inches.		
Sal IV . .	11	11·83	27 } 87	16	4·29	70 } 160	1,100′
" III . .	48	12·14	26	22	8·69	34	
" II . .	43	9·86	34	19	5·04	56	
" I . .	7	9·89	34	2	6·62	45	
" IA .	...	...	...	...	...	...	
Total . .	109	...	121	59	...	205	

Class.	SANMANTHAPLA 17 YEARS. 2-acre plot, thinned. No. of trees.	Average increase.	Time required to get through the class.	½-acre plot, unthinned. No. of trees.	Average increase.	Time required to get through the class.	Remarks.
		Inches.			Inches.		
Sal IV . .	3	11·88	28 } 87	6	3·13	98 } 190	1,100′
" III . .	46	10·57	29	21	5·75	53	
" II . .	52	10·22	30	13	7·99	39	
" I . .	11	8·88	34	3	8·02	38	
" IA .	...		...	1	1·25	235	
Total .	...	...	121	54	...	473	

(i) KUMAUN DIVISION—*concld.*

Class.	Aonla Khera South, Compartment 5, unthinned.			Chilla, Compartment 3, unthinned.			Remarks.
	No. of trees.	Average increase.	Time required to get through the class.	No. of trees.	Average increase.	Time required to get through the class.	
		7 years.			7 years.		7 years.
		Inches.			Inches.		
Sal IV .	7	4·67	23 } 52	5	3·51	31 } 78	2,400′—2,800′
„ III .	99	3·72	29	11	2·31	47	
„ II .	...	...	...	5	2·77	40	
„ I .	...	...	..	2	1·25	88	
„ IA .	...	...	...	...	...	...	
Total .	106	...	52	23	...	206	

(ii) GARHWAL DIVISION.

Class.	North Patli Dun, 13 years.						Remarks.
	2 acre plot thinned.			½ acre plot, unthinned.			
	No. of trees.	Average increase.	Time required to get through the class.	No. of trees.	Average increase.	Time required to get through the class.	
		Inches.			Inches.		
Sal IV .	37	7·56	31 } 81	97	2·75	85 } 141	1,420′
„ III .	88	9·39	25	52	4·2	56	
„ II .	29	9·42	25	..	...	...	
„ I .	3	9·83	24	2	1·33	176	
„ IA .	...	..	...	...	...	...	
Total .	157	...	105	151	...	317	

(ii) GARHWAL DIVISION—*contd.*

Class.	SOUTH PATLI DUN, 13 YEARS.						Remarks.
	2 acre plot, thinned.			½ acre plot, unthinned.			
	No. of trees.	Average increase.	Time required to get through the class.	No. of trees.	Average increase.	Time required to get through the class.	
		Inches.			Inches.		
Sal IV	58	12·61	19	142	5·13	46	1,300'
" III	92	7·75	30 } 68	26	4·07	58 } 141	
" II	1	12·58	19	2	6·37	37	
" I	...	...	...	..	.	...	
" IA	...	..	.	2	3·37	70	
Total	151	...	68	172	...	211	
	AMTANALA, 16 YEARS.						
	2 acre plot, thinned.			½ acre plot, unthinned.			
		Inches.			Inches.		
Sal IV	1	9·92	29	5	4·15	83	
" III	11	11·87	25 } 81	30	5·97	57 } 191	1,800'–1,900'
" II	84	10·68	27	24	6·71	51	
" I	18	10·11	28	3	14·62	28	
" IA	...	...	...	...	...	...	
Total	114	...	109	62	...	219	

(ii) GARHWAL DIVISION—*concld.*

Class	REHAR, 13 YEARS.						REMARKS
	2 ACRE PLOT, THINNED.			½ ACRE PLOT, UNTHINNED.			
	No. of trees.	Average increase.	Time required to get through the class.	No. of trees.	Average increase.	Time required to get through the class.	
		Inches.			Inches		
Sal IV .	17	9·72	24	24	3·34	70	
,, III .	81	8·97	26 } 74	33	5·40	43 } 150	1,000'
,, II .	29	9·61	24	13	6·39	37	
,, I .	1	11·58	20	1	4·50	52	
,, IA .	...	...	...	...	...	...	
Total .	128	...	94	71	...	202	

(iii) GANGES DIVISION.

Class.	CHAUKHAMB, 12 YEARS.						REMARKS.
	2 ACRE PLOT, THINNED.			1 ACRE PLOT UNTHINNED.			
	No. of trees.	Average increase in 12 years.	Time required to get through the class.	No. of trees.	Average increase in 12 years.	Time required to get through the class.	
		Inches			Inches.		
Sal IV .	72	6·1	35	21	2·45	88	
,, III .	108	7·4	29 } 94	51	52·9	41 } 163	2,000'
,, II .	30	7·15	30	18	6·37	34	
,, I .	5	5·97	36	1	7·05	31	
,, IA .	5	5·54	39	1	5·3	41	
Total .	220	...	169	92	..	235	

(iii) GANGES DIVISION—*contd.*

Class.	ANDHERMAJHERA, 12 YEARS. 2 ACRE PLOT, THINNED. No. of trees.	Average increase in 12 years.	Time required to get through the class.	½ ACRE PLOT, UNTHINNED. No. of trees.	Average increase in 12 years.	Time required to get through the class.	REMARKS.
		Inches.			Inches.		
Sal IV .	20	4·23	51	22	3·01	72	
" III .	114	6·02	36 } 116	48	5·34	41 } 145	1,100'
" II .	28	7·45	29	13	6·75	32	
" I	1	5·6	39	1	8·4	25	
" IA .	...	...		...	...	...	
Total .	163	...	155	84	...	170	

SECTION 8.—FIRE PROTECTION.

Under this head it is only proposed to consider the influence of frequent forest fires on the volume and money development of the Sal, since purely sylvicultural questions lie outside the scope of this inquiry.*

Sample plots to determine the relative rate of the mean annual girth increment in burnt and in unburnt middle-aged and old Sal woods have been prescribed from time to time, notably in the Tirsal and Molawalla reserves of the Siwalik Division, and elsewhere; but no data tending to elucidate the problem are at present available: and experiments bearing on very young trees or seedlings 1—3 year old have never been undertaken.

The effect of forest fires on the development of the money value of Sal woods, more especially as regards the quality (value) of the timber produced, has not been brought under investigation.

*Mr. S. Eardley-Wilmot's Note on the Sal (op. cit. page 4) may be consulted in conjunction with the remarks contained in the Resolution on Forest Administration in Assam during 1905-1906.

Part V.

THE DEVELOPMENT OF THE MONEY VALUE OF SAL SINGLE TREES AND WHOLE WOODS.

PART V.

THE DEVELOPMENT OF THE MONEY VALUE OF SINGLE TREES AND WHOLE WOODS.

SECTION 1. PRELIMINARY MATTERS.

In early youth the diameter of a tree is so small that it has practically no market value. But as soon as the tree reaches a certain diameter, it begins to acquire value : the price per unit of volume increases with every increase in diameter and, in addition, with every increase in volume the proportion of the more valuable timber (*i.e.*, wood of larger dimensions) increases. The growth in value of a wood or of a tree thus depends both on the diameter increment and on the proportion of timber to small wood—questions which have already been dealt with.

The ratio between the money yield of a crop and the capital invested gives the rate of interest, and the determination of this quantity, and of the current forest per cent. or *Weiserprocent** enables the forester to adopt the highest possible rotation without the interest falling below a fixed minimum.

The rate of interest obtained from a wood, like the total money value, depends on the dimensions (volume) and on the value of the varying grades of produce yielded by a wood under different rotations. Nevertheless the fact must be clearly recognised that, whatever may be the value of the higher grades of timber, a high rotation will ever be synonymous with a low rate of interest—a fact which necessitates State management for the production of the largest sizes of timber.

Finally, in a forest under intense management, thinnings have a decided effect on the growth of the money value of a crop : a question which may become of some importance in the management of future Sal forests.

SECTION 2. THE MONEY VALUE OF A CROP OR TREE. MONEY YIELD TABLES.

Laws which govern the development of the money value of trees and woods in general :—

I. With the more valuable species of timber trees, as a general rule, the value per unit increases with the diameter, unless extraction becomes impossible beyond a certain size.

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* See Schlich's Manual of Forestry, Vol. III, page 190.

II. Trees of inferior species, those yielding timber of poor quality, the uses for which are limited, frequently cease to increase in value after attaining a certain girth.

III. Trees of particular dimensions, (mine props, hop poles, etc.) may have high temporary values which fall as soon as those dimensions are exceeded: but the value increment subsequently follows the laws above enunciated, increasing with the diameter.

IV. The value of a wood increases faster than its volume, since the rate at which the value increases depends both on the volume increment and on the rise in price per unit of volume.

V. The current annual value increment, like the volume increment, steadily rises during early youth, reaches a maximum, and then falls: the more favourable the locality the earlier will the current annual value increment culminate.

VI. Though the mean annual value increment may be said to follow the same course as the current annual value increment it seldom, if ever, culminates before the exploitation of the wood.

VII. In a systematically worked forest with a normal series of age gradations, the higher the rotation, the greater the value of the growing stock. In other words, the rotation of the highest income seldom culminates before the age of exploitation.

The value of single trees or whole woods of a given age is obtained from volume tables* by ascertaining the local prices of the several grades of timber and firewood. In this way also Money Yield Tables may be prepared: but such tables can only be of purely local or temporary application, especially in India.

Moreover, under existing market conditions, the laws which govern the development of the money value of single trees and woods as above enunciated do not appear to be altogether applicable to the Sal. For instance, the money value of Sal timber per unit of volume, taking the rates levied by the Forest Department at forest depôts for trees above 3 feet in girth at breast-height, does not as a rule increase appreciably with the diameter. The following table gives examples of the values of Sal timber of various grades :—

* See pages 103 and 109, *ante*.

Rates levied by the Forest Department on various grades of Merchantable Sal Timber.

Forest Division.	Description of Produce.	—	Value.	Remarks.
	Punjab.		R a. p.	
Simla Division.	Ballas, 25′ 24″ girth . .	Per cub. ft.	0 5 9	Balla=6·25 c. ft.
	Ballu, 20′ 12″ ,, .	,,	0 6 5	Ballu=1·25 ,,
	Tors, 12′ 14″ ,, .	,,	0 8 6	Tors=1·00 ,,
	United Provinces			
Naini Tal Division.	Standing tress—			
	Under 1½′ girth .	Per tree.	0 8 0	Average Volume of trees not known.
	1½′—3′ ,, . .	,,	1 0 0	
	3′—4½′ ,, . .	,,	3 8 0	
	4½′—6′ ,, . .	,,	8 0 0	
	6′—7′ ,, . .	,,	15 0 0	
	Bengal.			
Tista Valley Division.	Poles —			
	Up to 1 foot girth .	Each.	0 2 0	Average Volume of poles of different girths not known.
	1 to 2 feet ,,	,,	0 6 0	
	2 ,, 3 ,, ,, .	,,	0 12 0	
Singbhum Division.	Standing trees—			
	3 to 3½ feet girth .	Per cub. ft.	0 2 0	Girth measured at breast-height.
	3½ ,, 4 ,, ,, .	,,	0 3 0	
	4 ,, 5 ,, ,, .	,,	0 4 0	
	5 ,, 6 ,, ,, .	,,	0 5 0	
	Over 6 ,, ,,	,,	0 6 0	
	Eastern Bengal and Assam.			
Jalpaiguri Division.	Timber .	Per cub. ft.	Four to seven annas according to girth.	

SECTION 3.—THE RATE OF INTEREST.

Laws which govern the development of the rate of Interest :—

I. The rate of interest yielded by a wood, the proportion existing between the yield and the capital invested, varies with the rotation.

II. The rate of interest is very low during early youth ; it then rises rapidly ; reaches a maximum, the earlier, the quicker the growth in value. After culmination the rate of interest steadily falls as the rotation rises.

The rate of interest of a forest under different rotations, like the total money value, depends on the quantity and on the value of the varying grades of produce yielded by a wood at different ages. Nevertheless it must be clearly understood that a very high rotation will invariably mean a low rate of interest, however much the value per unit may increase with age.

Appendices.

A.—Sylvicultural Problems relating to the Sal.

B. On the Growth of the Companion Trees of the Sal.

C.—Map showing distribution of Sal Reserved Forests.

APPENDIX A.

SYLVICULTURAL PROBLEMS RELATING TO THE SAL.*

The more important Sylvicultural Problems relating to the Sal, now requiring investigation, are the following :—

(*i*) *The effects of Fire-Protection.*—The enquiry may be limited to the effects of complete protection from fire on regeneration in localities where the rainfall exceeds 150 inches. There can be no question as to the highly injurious effects of fires on the higher well-drained lands, or even of continual fires on low lands with regard to the ultimate crop, and with continual fires the forests are apt to give place to grass.

(*ii*) *Coppice Reproduction.*—The results of Coppice Fellings in Eastern Bengal are said to prove that Sal Coppice cannot be considered a practicable method under the conditions stated in (i), whether with or without Standards.

(*iii*) *The best method of treating forests in which Sal occurs scattered in Mixed Forest.*—The problem concerns exclusively the increase of the Sal.

(*iv*) *The restocking of blanks and Savannahs is related to* (i).—Savannahs are of two kinds, namely, High and Low land ; the former are almost entirely due to *Fire* or *old cultivation.* The Working-Plan for the Jalpaiguri reserves, Bengal, partly deals with this question ; and experiments have also been taken in hand in Kheri.

(*v*) Allied to (ii) *is the best method of coppicing Sal,* a question that is now being investigated at the Imperial Forest Research Institute, Dehra Dun.

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* Note by H. H. Haines, F.L.S., F.C.H., Imperial Forest Sylviculturist, Imperial Research Institute, Dehra Dun, United Provinces.

Attention may also here be drawn to the following questions requiring careful investigation, namely :—

(1) The presence or absence of annual rings in the wood, which closely concerns the quality of the timber.

(2) Germination and development of seedlings, coupled with the study of the annual dying back.

(3) Power of producing root suckers and coppice shoots ; quality of the coppice shoots, their longevity and power of producing fertile seed.—A.M.F.C.

(*vi*) *The best Sylvicultural method of treating Sal under High Forest.* —This is not known; all Working-Plans excepting the experimental Working Circles in the Dehra Dun, United Provinces, prescribing Improvement or Selection Fellings.

(*vii*) *The regulation of Thinnings* in Sal forests.

APPENDIX B.

ON THE GROWTH OF SOME OF THE COMPANION TREES OF THE SAL.

The following are the more important Companion trees of the Sal :—

Terminalia tomentosa.	Anogeissus latifolia.
Terminalia belerica.	Casearia glomerata.
Terminalia Chebula.	Casearia tomentosa.
Lagerstrœmia parviflora.	Randia dumetorum.
Adina cordifolia.	Bridelia retusa.
Stephegyne parvifolia.	Glochidion velutinum.
Eugenia Jambolana.	Mallotus philippinensis.
Eugenia operculata.	Ficus bengalensis.
Grewia asiatica.	Ficus Rumphii.
Holarrhena antidysenterica.	Ficus infectoria.
Wrightia tomentosa.	Dillenia pentagyna.
Stereospermum suaveolens.	Ægle Marmelos.
Garuga pinnata.	Careya arborea.
Bassia latifolia.	Diospyros tomentosa.
Miliusa velutina.	Phyllanthus Emblica.
Kydia calycina.	*Cedrela Toona.
Buchanania latifolia.	*Trewia nudiflora.
Schleichera trijuga.	Schima Wallichii.
Odina Wodier.	Callicarpa arborea.
Ougeinia dalbergioides.	Sterculia villosa.
Butea frondosa.	†Elæodendron glaucum.
Cassia Fistula.	Flacourtia Ramontchi.
Bauhinia malabarica.	Semecarpus Anacardium.

Dendrocalamus strictus.

* In damp places.
† Not common.

Dalbergia Sissoo and Acacia Catechu form gregarious patches along streams in Sal forests of the Sub-Himalayan tract, though not actually mixed with the Sal.

Very little is known regarding the development in volume of these several species : but such trees as fall within the area of the Sal Sample Plots, detailed on pages 48 to 93 of this Note, have frequently also been kept under observation and measured periodically. A few data are therefore available bearing on their growth in diameter or girth. Nevertheless, these are based on insufficient measurements, and they

almost invariably relate to neglected trees, which have grown up under very abnormal conditions. The question should in each case be carefully considered whether any useful purpose is gained by continuing to measure year after year trees, taken at random, without due consideration being paid to their condition or their environment. The following statements will in many cases indicate how far a careful scrutiny of the type trees at present under observation is desirable. No height measurements have been recorded.

MEAN ANNUAL GIRTH INCREMENT TABLES.

(*Girth classes*—0′—1½′ = Class V ; 1½′—3′ = Class IV ; 3′—4′ = Class III ; 4½′—6′ = Class II; 6′—8′ = Class I.)

Acacia Arabica.

Name of Province.	Name of Forest Division.	Name of sample plot.	Number of trees under observation.	Number of years under observation.	Girth classes represented.	Mean Annual Increment.	REMARKS.
United Provinces.	Gonda	Sakra No. 3 . .	1	2	IV	0·40	

Acacia Catechu.

Province.	Forest Division.	Sample plot.	Number of trees under observation.	Number of years under observation.	Girth classes represented.	Mean Annual Increment.	REMARKS.
United Provinces.	Kheri .	Sample plot No. VI .	94	...	II, III, IV	0·41	Measurements taken in a pure khair wood, situated within the limits of a Sal forest.

Adina Cordifolia.

Province.	Forest Division.	Sample plot.	Number of trees under observation.	Number of years under observation.	Girth classes represented.	Mean Annual Increment.	REMARKS.
United Provinces.	Ganges	Giwain	1	4	IV	0·97	Thinned.
	„	„	3	12	IV	0·27	Unthinned.
United Provinces.	Kumaun	Mona No. III	5	..	...	...	Trees under observation show no growth for 11 years.
United Provinces.	Gonda	Chandanpur No. I	3	2	IV	0·50	
		„ No. II	1	2	IV	0·55	

Anogeissus Latifolia.

United Provinces.	Ganges	Chaukhamb A	7	17	IV	0·26	Thinned.
		„ B	1	17	IV	0·47	Unthinned.
		Jogichar	2	12	IV	0·14	Thinned.
		Giwain A	2	4	IV	0·27	Thinned.
		„ B	10	12	IV	0·63	Unthinned.
United Provinces.	Kumaun	Khonani	1	6	IV	0·20	Unthinned.
United Provinces.	Gonda	Chandanpur No. I	13	2	III. IV	0·16	
	„	Sakra No. III	16	2	IV	0·24	

Artocarpus Lakoocha.

United Provinces.	Gonda	Chandanpur No. 2	1	2	IV	0·35	
	„	Sakra No. 3	4	2	IV	0·14	

Bassia Latifolia.

Province.	Forest Division.	Sample Plot.	Number of trees under observation.	Number of years under observation.	Girth classes represented.	Mean Annual Increment.	REMARKS.
United Provinces.	Gonda	Chandanpur No. I .	3	2	IV	0·9	
	„	„ No. II .	1	2	IV	0·15	
	„	Sakra No. III . .	1	2	IV	0·20	

Bridelia Retusa.

United Provinces.	Ganges	Giwain . . .	1			0·31	Thinned.

Butea Frondosa.

United Provinces.	Ganges	Chaukhamb . .	3	17	IV	0·47	Thinned.
	„	Jogichaur . . .	2	4		0·56	Unthinned.
	„	Barswar . . .	1	4	IV	0·19	Thinned.

Buchanania Latifolia.

United Provinces.	Ganges.	Andhermajhera . .	8	17	IV, V	0·23	Thinned
	„	Giwain . . .	14	4	IV	0·56	„
	„	Barswar . . .	11	4	IV	0·25	„
	„	„ . . .	10	4	IV	0·20	Unthinned.
	„	Jogichaur . . .	1	4	III	0·15	„
	Garhwal	Southern Patli Dun .	2	19	IV	0·07	„
	Gonda.	Chandanpur No. I .	5	2	IV	0·33	„

Casearea Graveolens.

Province.	Forest Division.	Sample Plot.	Number of trees under observation.	Number of years under observation.	Girth classes represented.	Mean Annual Increment.	Remarks.
United Provinces.	Ganges	Chaukhamb . .	2	17	IV	0·85	Thinned.
	„	„ . .	1	17	IV	0·10	Unthinned.
	Garhwal	South Patli Dun .	2	19	I	0·15	„
	„	Domanda . .	1	19	IV	0·13	„

Cassia Fistula.

United Provinces.	Ganges	Andhermajhera .	1	17	IV	0·32	Thinned.
	„	Jogichaur . . .	1	12	IV	0·52	„
	„	Giwain . . .	1	12	IV	0·79	Unthinned.

Casearia Tomentosa.

United Provinces.	Ganges	Jogichaur . . .	1	12	I*	0·09	* Tree S½ girth thinned.
	„	Giwain . .	2	4	IV	0·22	Thinned.
		„	4	12	IV	0·34	Unthinned.
United Provinces.	Kumaun	Lakhmanandi .	1	..	...	...	No increment shown.

Cedreta Toona.

United Provinces.	Garhwal	Mandal . .	1	1	IV	0·42	Unthinned.

Elæodendron Roxburghii.

Province.	Forest Division.	Sample Plot.	Number of trees under observation.	Number of years under observation.	Girth classes represented.	Mean Annual Increment.	REMARKS.
United Provinces.	Ganges	Chaukhamb . .	2	17	IV	0·35	Thinned.
	„	Barswar . . .	4	4	IV	0·11	„
	„	„ . . .	8	4	IV	0·20	Unthinned.

Eugenia Jambolana.

United Provinces.	Ganges	Chaukhamb . .	2	17	IV	0·70	Thinned.
	„	Giwain . . .	1	4	IV	0·13	„
	„	Barswar . . .	4	4	III, IV	0·39	„
	„	„ . . .	10	4	III, IV	0·28	Unthinned.
	„	Jogichaur . . .	1	4	I	0·32	„
United Provinces.	Garhwal	Mandal . . .	2	1	IV	0·42	„
	„	„ . . .	1	1	IV	0·37	Thinned.
	„	S. Patli Dun . .	5	19	IV, V	0·27	Unthinned.
	„	Domanda . .	1	19	IV	0·36	„
United Provinces.	Kumaun	Silani . . .	4	11	II, III, IV	0·61	„
United Provinces.	Gonda	Chandanpur No. I .	1	2	V	0·15	
	„	Sakra No. III .	2	2	IV	0·30	

Eugenia Operculata.

United Provinces.	Ganges	Barswar . . .	2	4	IV	0·19	Thinned.
	„	„ . . .	3	4	IV	0·44	Unthinned.
United Provinces.	Garhwal	S. Patli Dun . .	2	19	IV, V	0·17	„

Flacourtia Ramontchi.

Province.	Forest Division.	Sample Plot.	Number of trees under observation.	Number of years under observation.	Girth classes represented.	Mean Annual Increment.	REMARKS.
United Provinces.	Ganges	Kauria	1	4	III	0·20	Thinned.
	„	Barswar	1		IV	0·31	Unthinned.

Garuga Pinnata.

United Provinces.	Ganges	Jogichaur	1	4	IV	0·52	Unthinned.

Grewia Vestita.

United Provinces.	Ganges	Chaukhamb . .	2	17	IV	0·54	Thinned.
	„	Kauria . . .	1	4	IV	0·09	„
	„	Giwani . . .	3	4	IV	0·41	„

Holarrhena Antidysenterica.

United Provinces.	Ganges	Andhermajhera .	2	17	V	0·41	Unthinned
United Provinces.	Garhwal	S. Patli Dun . .	1	19	V	0·05	„
„	„	Domanda . . .	1	19	IV	0·12	„

Lagerstrœmia Parviflora.

Province.	Forest Division.	Sample Plot.	Number of trees under observation.	Number of years under observation.	Girth classes represented.	Mean Annual Increment.	REMARKS.
United Provinces.	Ganges	Andhermajhera . .	10	17	III, VI, V	0·12	Thinned.
		„ .	2	17	IV	0·05	Unthinned.
	„	Kauria . . .	3	4	IV	0·14	Thinned.
United Provinces.	Garhwal	Amtanala . . .	24	25	I, IV	0·41	Unthinned.
	„	S. Patli Dun . .	3	19	V*	0·23	*9′—13′ girth.
United Provinces.	Kamaun	Samnan Thopla .	5	...	...	0·09	Measurements unreliable.
	„	Lakhmanmandi . .	3	...	...	...	„
	„	Aonlakhera . .	1	4	V	0·40	Unthinned.
	„	Chilla . . .	4	11	II—III	0·34	Unthinned.
	„	Khonani . . .	5	6	II—IV	0·31	Unthinned.

Mallotus Philippinensis.

United Provinces.	Ganges	Chaukhamb . .	17	17	IV, V	0·37	Thinned.
	„	„ . .	1	17	III	0·47	Unthinned.
United Provinces.	Garhwal	S. Patli Dun . .	11	19	IV, V	03·2	„
	„	Domanda . . .	2	19	IV, V	0·20	„
United Provinces.	Kumaun	Sanman Thopla .	5	...	...	0·09	Measurements unreliable, unthinned.
	„	Salani . . .	5	4	IV	0·67	Unthinned.
	„	Lakhmanmandi . .	1	11	IV	0·32	

Careya Arborea.

Province.	Forest Division.	Sample Plot.	Number of trees under observation.	Number of years under observation.	Girth classes represented.	Mean Annual Increment.	REMARKS.
United Provinces.	Ganges	Chaukhamb . .	5	17	I—IV	0·33	Thinned.
	"	" . .	1	17	IV	0·29	Unthinned.
	"	Jogichaur . . .	2	12	IV	0·18	Thinned.
United Provinces.	Garhwal	Rehar . . .	1	19	IV	0·05	Unthinned.

Miliusa Velutina.

United Provinces.	Ganges	Andhermajhera . .	3	17	IV	0·19	Thinned.
United Provinces.	Gonda	Chandanpur No. I .	1	2	IV	0·15	

Odina Wodier.

United Provinces.	Garhwal	Domanda . . .	1	19	IV	0·32	Unthinned.

Ougeinia Dalbergioides.

United Provinces.	Ganges	Chaukhamb . .	3	17	IV	0·13	Thinned.
	"	Giwain . . .	15	4	IV	0·43	"
	"	" . . .	13	12	III, IV	0·43	Unthinned.
	"	Barswar . . .	7	4	IV	0·39	Thinned.
	"	" . . .	5	4	III, IV	0·27	Unthinned.
United Provinces.	Garhwal	Mandal . . .	10	1	IV	0·21	Unthinned.
	"	" . . .	7	1	III, IV	0·37	Thinned.
	"	Rahar . . .	2	19	IV	0·29	Unthinned.

Ougeinia Dalbergioides—contd.

Province.	Forest Division.	Sample Plot.	Number of trees under observation.	Number of years under observation.	Girth classes represented.	Mean Annual Increment.	REMARKS.
United Provinces.	Kumaun	Mora No. 1 . .	8	11	III—IV	0·52	
	"	" " 4 . .	13	...	...	...	No increment for 11 years.
	"	" " 5 . .	6	...	...	...	No increment for 11 years.
United Provinces.	Gonda	Chandanpur No. 1 .	1	2	IV	0·10	

Phyllanthus Emblica.

Province.	Forest Division.	Sample Plot.	Number of trees under observation.	Number of years under observation.	Girth classes represented.	Mean Annual Increment.	REMARKS.
United Provinces.	Ganges	Chaukhamb . .	9	17	II–IV	0·24	Thinned.
	"	"	3	17	IV	0·07	Unthinned.
	"	Andhermajhera . .	3	17	IV	0·57	Thinned.
	"	" . .	5	17	IV	0·18	Unthinned.
	"	Kauria . . .	1	5	III	0·18	"
	"	Giwain . . .	2	4	IV	0·19	Thinned.

Schleichera Trijuga.

Province.	Forest Division.	Sample Plot.	Number of trees under observation.	Number of years under observation.	Girth classes represented.	Mean Annual Increment.	REMARKS.
United Provinces.	Gonda	Chandanpur No. I .	1	2	V	0·15	

Semecarpus Anarcardium.

Province.	Forest Division.	Sample Plot.	Number of trees under observation.	Number of years under observation.	Girth classes represented.	Mean Annual Increment.	REMARKS.
United Provinces.	Ganges	Chaukhamb . .	6	17	IV	0·14	Thinned.
	"	Barswar . . .	6	4	IV	0·44	"
	"	" . . .	14	4	IV, V	0·20	Unthinned.
United Provinces.	Garhwal	Rehar . . .	1	19	IV	0·44	Unthinned.
United Provinces.	Gonda	Chandanpur No. I .	1	2	V	0·10	

Stereospermum Suaveolens.

Province.	Forest Division.	Sample Plot.	Number of trees under observation.	Number of years under observation.	Girth classes represented.	Mean Annual Increment.	REMARKS.
United Provinces.	Ganges	Andhermajheri . .	7	17	III, IV	0·30	Thinned.
	,,	,, . .	3	17	III, IV	0·15	Unthinned.
	,,	Jogichaur . . .	5	12	III, IV	0·31	Thinned.
	,,	,, . .	9	4	IV	0·27	Unthinned.
	,,	Kauria . . .	2	4	IV	0·12	Thinned.
	,,	,, . . .	1	5	IV	0·47	Unthinned.
	,,	Gewain . . .	2	12	IV	0·31	,,
United Provinces.	Garhwal	Rehar . . .	15	19	IV	0·20	,,

Terminalia Belerica.

United Provinces.	Ganges	Chaukhamb . .	6	17	III, IV	0·34	Thinned.
	,,	Jogichaur . . .	1	...	III	0·80	Unthinned.
	,,	Kauria . . .	1	4	I	0·49	Thinned.
	,,	Gewain . . .	2	12	IV	0·10	Unthinned.
United Provinces.	Kumaun	Khonani . . .	2	6	III	0·46	,,

Terminalia Chebula.

United Provinces.	Ganges	Chaukhamb . .	10	17	II—IV	0·56	Thinned.
	,,	,, . .	1	17	II	0·58	Unthinned.
	,,	Jogichaur . . .	1	4	IV	0·38	,,
	,,	Barswar . . .	7	4	IV	0·21	Thinned.
	,,	,, . . .	8	4	IV	0·32	Unthinned.

Terminalia Tomentosa.

Province.	Forest Division.	Sample Plot.	Number of trees under observation.	Number of years under observation.	Girth classes represented.	Mean Annual Increment.	REMARKS.
United Provinces.	Dehra Dun (Siwalik.)	Jamna . . .	1		IV	0·49	
	„	Malhan . . .	7		IV, V	0·88	
	„	Nagsidh . . .	72	7 to 10 years.	II, III, IV, V	0·52	
	„	Thano . . .	2		III, V	0·27	
	„	Tirsal . . .	2		III, IV	0·72	
United Provinces.	Ganges	Chaukhamb . .	5	17	I, III	0·54	Thinned.
	„	„ . .	1	17	III	0·21	Unthinned.
	„	Barswar . . .	8	4	IV	0·53	Thinned.
	„	„ . . .	3	4	II, IV	0·27	Unthinned.
United Provinces.	Garhwal	Mandal . . .	5	1	I, IV	0·45	„
	„	„ . . .	4	1	I, IV	0·40	Thinned.
United Provinces.	Kumaun	Khonani . . .	1	1	IV	0·45	Unthinned.
	„	Selani . . .	18	11	I, IV	0·68	„
	„	Mona No. I . .	4	11	...	0·05	
	„	„ No. II . .	5	11	II—IV	0·11	
	„	„ No. 3 . .	12	11	III, IV	0·20	37 trees under observation, results unreliable.
	„	„ No. 3 . .	18	...	...	...	Unthinned, no increment during 11 years.
	„	„ No. 4 . .	3	...	...	...	
	„	„ No. 5 . .	1	...	...	...	
United Provinces.	Kheri . „	West Sal, South Plot No. I.	12	1	III, IV	0·68	
		West Sal, South Plot No. II.	19	1	II, IV	0·26	

Terminalia Tomentosa—contd.

Province.	Forest Division.	Sample Plot.	Number of trees under observation.	Number of years under observation.	Girth classes represented.	Mean Annual Increment.	REMARKS.
United Provinces.	Bahraich	Chakia Coupe III .	15	8	IV, V	0·43	
	,,	,, Compartment 15	11	8	IV	0·42	
	,,	,, Coupe IV .	2	6	III, IV	1·25	
	,,	Charda ,, IX .	3	8	IV	0·20	
	,,	,, ,, V .	8	8	IV	0·30	
	,,	Gubbapur ,, VII .	5	8	III, IV	0·50	
	,,	,, ,, III .	14	8	III—IV	0·52	
	,,	,, ,, V .	1	8	III	0·63	
United Provinces.	Gonda	Sakra No. III .	20	2	III—V	0·22	
	,,	Chandanpur No. I .	11	2	III—IV	0·38	
	,,	,, No. II .	7	2	III—V	0·62	

Xylosma Longifolium.

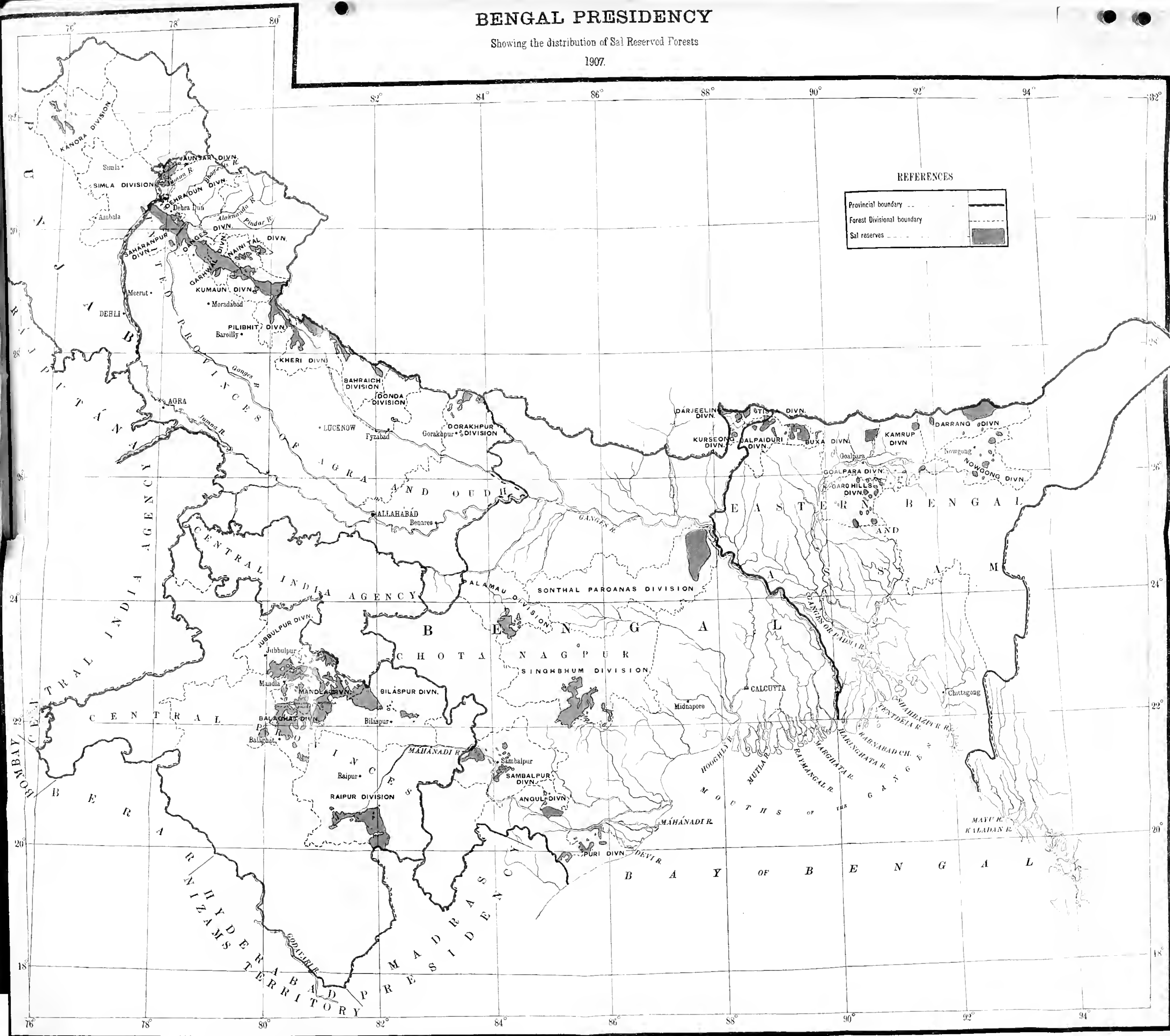
United Provinces	Ganges	Andermajhera . .	4	17	V	0·11	Thinned.
	,,	,, . .	5	17	IV, V	0·11	Unthinned.
	,,	Jogichaur . . .	5	4	IV	0·14	,,
	,,	Kauria . . .	2	4	IV	0·22	Thinned.
	,,	,, . . .	1	5	III	0·25	Unthinned.

G. I. C. P. O.—No. 911 R. & A.—18-4-1908.— 700.—P. O. G.

BENGAL PRESIDENCY

Showing the distribution of Sal Reserved Forests

1907.



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November 1907.

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VOL. I. PART III.

THE

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INDIAN FOREST RECORDS.

Vol. I.] 1908. [Part III.

Pterocarpus dalbergioides, Roxb.:

Andaman Padouk.

By B. B. OSMASTON, F.C.H.
Deputy Conservator of Forests, Andamans.

1. *Habit.*—A very large semi-deciduous tree reaching a height of 80 to 125 feet with a clear bole of 20 to 50 feet and a girth of 10 feet. Even larger trees than this occur, stems from 12 to 16 feet in girth being occasionally met with.

The trunk is frequently much buttressed; this is especially the case with trees growing on low-lying ground.

2. *Distribution.*—The Andaman Padouk tree is confined to the Andaman Islands, being found throughout the group in suitable places. It does not extend to the Nicobar Islands, nor yet to the Cocos, Narcondam or Barren Island. The total area of the Andaman Islands being about 1,951 square miles, it has probably a smaller area of distribution than any other important Indian forest tree.

3. *Timber.*—Andaman Padouk yields a valuable ornamental wood, the colour of which varies in shade from a deep crimson, through cherry red, dull red, pink and reddish brown to brown.

The logs yielding the very best crimson-red wood constitute only about 5 per cent. of the yield, but about 70 per cent. of the logs extracted yield red wood of various shades fit for the foreign market.

The remaining 30 per cent. consists of reddish brown or brown timber, the "off coloured Padouk," which is equal to the former in strength and durability, and, indeed, in every respect excepting colour.

About 95 per cent. of the Padouk logs extracted float in sea water after they have been felled a month, and well seasoned wood weighs

about 48 lbs. to the cubic foot. It is very durable, exceedingly strong and seasons easily and well either immersed in sea water or in the dry. Sawn timber is practically immune from the attacks of insects, including the white ant, but is bored by the marine worm.

It works well, does not warp or crack and takes a fine polish.

The red wood darkens on exposure to light, becoming ultimately dark brown. This alteration in colour is confined to the immediate surface.

There is a distinct sapwood varying from 1 to 3 inches in thickness, which is yellowish white in colour and rots rapidly.

The timber, owing to its durability, strength and seasoning properties, is admirably suited for construction, but owing to the high price commanded by the red-coloured wood it is chiefly used for decorative purposes, such as panelling, billiard tables, etc., and also in America in the construction of Pullman Cars.

Planks 30 inches and even occasionally 40 inches wide are obtainable from large logs, but the finest broad slabs are yielded by the buttresses which not unfrequently disfigure the lower portions of the stem. Some of these buttresses are very large and the wood they contain is generally of excellent colour and fine grain.

One such buttress recently yielded an oval table, now in the possession of Lord Kitchener, measuring 12 feet 9 inches by 7 feet.

4. *Conditions of Growth.*—Padouk is not gregarious, but is found scattered throughout the mixed deciduous and semi-deciduous forests from near the level of the sea up to about 300 feet in elevation.

It is found at its best on the well-drained lower slopes of the hills and in the broader valleys, where it may often be seen growing alongside the tidal creeks just above the Mangrove belt.

It occurs mixed with various species, including *Lagerstrœmia hypoleuca*, *Terminalia bialata* and *T. procera*, *Albizzia Lebbek*, *Myristica Irya*, *Calophyllum spectabile*, *Bombax insignis*. *Artocarpus Chaplasha*, various *Sterculiæ* and many species of less importance.

None of these species are found in any large numbers on any given area, so that it not unfrequently happens that Padouk is the prevailing species in spite of the fact that, even in the richest Padouk forest, not more than three or four trees of this species will be found to the acre.

5. *Distribution of the Age Classes.*—A very large proportion of the stock of Padouk in all forests consists of mature or over-mature trees, the younger age classes being either very inadequately represented or not represented at all.

Young seedlings may, indeed, be discovered under seed bearers during the rains, but they cannot survive under the dense cover and there will be no trace of them the following year. Saplings and young poles, as well as trees below 6 feet in girth, are very scarce indeed except in the neighbourhood of Port Blair where clearings have admitted light which has permitted seedlings to hold their own.

This remarkable disparity in the age classes can only be explained by assuming that there has been a very recent change in the condition of the vegetation in the Andamans, the conditions under which the existing crop of mature and over-mature trees arose having given place to others unsuitable to the successful reproduction of Padouk.

It is no doubt difficult to indicate exactly the nature of such a change or how it could have arisen, but possibly an increase in moisture may have occurred which would favour shade-enduring species to the detriment of Padouk. We have, in any case, to face the fact that the young crop of Padouk is hopelessly inadequate to take the place of that which is now ripe for removal.

6. *Reproductive Power.*—Padouk reproduces powerfully from the stool, and this power is retained to a great age since quite old trees, on being felled, frequently send up strong shoots.

Good seed is produced in large quantities almost every year. Flowering takes place about June and the seeds ripen the following February or March. The fruits are conspicuous as early as August, so that a good seed year may be known six months before the seed is collected.

The pods, which do not dehisce, contain usually only one but rarely two fertile seeds, from which one, or in the latter case two, seedlings result.

Padouk seed, while on the tree, is very liable to the attacks of paroquets, which are found in large flocks and destroy a vast amount of seed during the cold weather months. When once the seed has been harvested it is safe provided it is kept in a dry place.

7. *Plantations.*—Artificial reproduction of Padouk is now being carried out upon a fairly large scale in the vicinity of Port Blair upon a modified Taungya system consisting in the clearing of the forest by felling and subsequent burning, after which Padouk seeds, or rather pods, are dibbled in at stake at 6 feet intervals, two at each stake.

The sowing is carried out in April and May immediately before the rains. Germination takes place throughout the rains and by the

end of the first year many of the seedlings will have attained a height of 5 feet.

In spite of this rapid growth the young Padouk would not have a chance of holding its own unaided in the struggle with the dense growth of weeds. consisting of various shrubs and climbers whose rate of growth far exceeds that of the Padouk.

It is difficult for any one unacquainted with the conditions of the vegetation in a warm and moist tropical climate such as belongs to the Andamans to fully realize the vigorous growth of such weeds. For the first two years weedings and cleanings have to be carried out repeatedly and continuously from April to December, passing completely over the area about once in two months. During the third and fourth years, cleanings are necessary, but at longer intervals, after which the plants should form a complete canopy, when occasional creeper cutting and thinnings will be the only operations called for.

The cost of such weedings and cleanings is naturally excessive and experiments have been made during the current year of combining the Padouk sowings with the cultivation of catch crops. With this object in view a few acres were sown with hill paddy, cotton and sessamum.

The cotton and sessamum did not do well but the paddy has been a decided success. It was sown early in June about a month after the Padouk and is now (October) about 3 feet high and in the ear. The Padouk seedlings among the paddy are about 18 inches high and appear at least as healthy as those elsewhere. It remains to be seen whether they will get on as well or better after the crop has been reaped.

At present it looks as if the value of the paddy crop would more than pay for the labour, and this being the case it will be profitable in future to sow the whole area of the Taungya with paddy.

8. *An Insect Pest.*—The Taungya system would appear to be well suited to the requirements of the young Padouk. There is, however, unfortunately an insect, a small weevil about $\frac{1}{8}$ inch in length, which attacks the young Padouk sapling, causing an immense amount of damage throughout such plantations.

The insect is most prevalent during the rainy months, *i.e.*, from May to October, during which period it rings all the tender shoots in a most systematic manner as fast as they are produced. The ringing is carried out 3 or 4 inches from the apex of the shoot, where it has a diameter of about $\frac{1}{10}$th of an inch, and if successful, as is usually the case, results in the portion above the ring falling off after a few days, to be replaced

by two or more new shoots, which are in their turn subjected to the same treatment.

The result is, as might be expected, a more or less stunted bush with no well defined leader, somewhat resembling a tea bush, the plucking in the case of the Padouk having been effected by the weevil.

In the cold weather or dry months the weevils are not much in evidence and, as there is no period of rest in the growth of the Padouk, the majority of the seedlings or saplings succeed in putting out a shoot several feet in length before the rains, when the pest again comes into prominence.

A certain number of the seedlings, however, probably the less vigorous or those which have suffered excessively from insect pruning, appear unable to make this effort, and they remain stunted and ultimately succumb. After the plants have reached their fourth year and are about 15 feet in height they appear to suffer much less from the weevil and it seems probable that as they grow older they will be less and less liable to this form of damage.

Unfortunately the oldest Padouk Taungya only dates back to 1903, but judging from the few regular plantations of older date young Padouk poles seem to be immune from such insect attacks. Scarcely anything is known at present of the life history of the Padouk weevil. So far it has been impossible to ascertain where the eggs are laid and the larvæ are not known.

The mature insect probes the tender shoots with its proboscis and drinks the exuding juice, but the object of ringing these same shoots is not known. It does not, however, appear to be connected in any way with the reproduction of the insect.

No means have as yet been devised for combating the attacks of this weevil, but possibly something may be done when more is known about its life history.

9. *A Boring Beetle.*—Padouk logs are usually stored in wet depôts (fenced enclosures of the sea). They may be safely kept in this way for a few months. but, if subjected to prolonged immersion, they are ruined by the marine worm (*Teredo navalis*). To avoid this an experiment was recently made in the dry storage of logs, which has, however, proved unsuccessful, the logs having been attacked by a small beetle belonging to the family *Scolytidæ* and genus *Xyleborus* or closely allied genus, which tunnels through the sapwood, penetrating more or less into the heartwood. The damage done by the borings of this insect is not really very serious as the tunnels do

not as a rule penetrate more than about half an inch into the heart-wood, but the sapwood is riddled by the borings and the heartwood usually shows the holes on its surface, which detract from the appearance and market value of a log.

Experiments are now being made in the Andamans with a view to ascertain, if possible, how the attacks of this insect may be prevented.

10. *Natural Reproduction.*—It has been stated above that under existing conditions Padouk reproduction is very rarely successful.

Quite recently, however, a large number of self-sown Padouk seedlings from 1 to 4 feet in height were discovered by the writer in a fuel coupe which had been felled over the previous year.

The felling had been a very heavy one, in fact almost a clear felling, only a few of the more promising timber trees having been left standing, a dense growth of inferior soft woods had sprung up forming a canopy about 8 to 10 feet high, and under this were found the seedlings of Padouk, all of which must have been a year old. It is doubtful if any of these seedlings would have survived unaided, and a heavy cleaning was made setting free their heads, and the result is at present most satisfactory.

This would seem to indicate that heavy fellings in Padouk forest often result in a crop of seedlings which with subsequent assistance might suffice to regenerate that forest as regards Padouk.

Unfortunately owing to the scattered position of the Padouk trees and to the fact that there is very little demand for the inferior species, these latter are not as a rule felled, and the holes in the canopy resulting from the felling of single trees here and there do not appear to be sufficient. The clearings, to be effective, should be larger in extent and it is essential that the seedlings, once they have sprung up, should receive periodical assistance or they will be suppressed by their more vigorous and more shade-enduring neighbours.

A Further Note on the Chilgoza Bark-boring Beetles of Zhob.

By E. P. STEBBING, F.L.S., F.Z.S., F.E.S.,

Embodying a Report by Captain E. H. S. James, I.A.
Political Agent, Zhob.

INTRODUCTION.

As a result of an inspection of the Shinghar Chilgoza (*Pinus Gerardiana*) Forest in North Zhob in the summer of 1905 I described, in the *Forest Bulletin* series,* several beetle pests belonging to the family Scolytidæ which were proving extremely destructive to the fine Shinghar Forest. In a subsequent Bulletin on the Chilgoza Forests of the Takht-i-Suleman † I was able to show that these pests were distributed throughout the Zhob Chilgoza areas and in the Forests of this species on the Takht-i-Suleman.

The beetles responsible for the damage done were three species of Scolytidæ. *Polygraphus Trenchi*, a new species described in Bulletin No. 3, an undetermined species of *Phlœosinus*, and *Pityogenes coniferæ* Steb., a beetle which ranges east into the Western Himalayan Coniferous forests.‡ It was shown that the first and second of these beetles were the most dangerous pests. After discussing the nature of the attack the question of the remedial measures to be adopted and the steps to be taken for the future protection of the forest was entered into in detail.§

* A Note on the Chilgoza (*Pinus Gerardiana*) Bark-boring Beetles of Zhob, Baluchistan. Forest Bulletin No. 3, Government of India Press, Calcutta (1905).

† On the Chilgoza Forests of Zhob and the Takht-i-Suleman. Forest Bulletin No. 7, Government of India Press, Calcutta (1906).

‡ *Departmental Notes on Insects which affect Forestry*, Vol. I, p. 242, and *Forest Bulletin*, No. 3, p. 14.

§ *Op. sit.*, No. 3, pages 19—22.

It is proposed here to briefly enumerate, from reports subsequently received through the Revenue Commissioner, Baluchistan, the steps taken by the Officers in charge of these forests to deal with the attack.

During the autumn of 1905, 82 badly attacked trees were felled and burnt in New Shinghar and as many as 268 infected trees were counted in Old Shinghar. The latter could not be taken in hand during 1905 owing to the want of funds and staff. In spite of the disparity in numbers of infested trees as shown by the countings made in the forest New Shinghar appears to have suffered more from the beetles than Old Shinghar. The large number of dead trees counted during the year in New Shinghar, 982, probably accounted for the smaller number of green ones attacked, since the trees had become more scattered.

Owing to difficulties in connexion with staff little work was undertaken during the year 1906, only 20 affected trees being cut out, making a total of 92 affected trees cut out and burnt since the commencement of the campaign against the beetles.

My examination of the infested trees in the Takht-i-Suleman area in November 1905 proved that the beetles pass through four generations in the year. From rough calculations made from measurements taken on the ground it was computed that an averaged sized tree in the Shinghar Forest could produce at a rough estimate a generation of 40,000 beetles. Allowing for 50 per cent. casualties this would give rise by the end of the year to a progeny of 40,000,000 beetles on the supposition that the insect passed through four generations only during this period.

From this calculation it follows that the removal of the 92 badly infested trees and the burning of the bark containing immature larvæ, pupæ and beetles may be safely estimated to have reduced the beetles that would have been present in the forest in the Spring of 1907 by some 500,000,000, allowing for very heavy mortality amongst the over-wintering larvæ and pupæ.

That the measures taken by the Political Agent, Colonel G. Chevenix-Trench, and the Extra Assistant Conservator of Forests, Bhai Sadhu Singh, were effective to a considerable degree in reducing very markedly the attack of these pests the following extract from a Note by Captain E. H. S. James, Political Agent in Zhob, " On the further ravages of the Borer Beetle of Shinghar for 1907 ", will abundantly prove, although some of the conclusions arrived at by Captain James are perhaps susceptible of some modification. Captain James' Report is as follows :—

" Before proceeding to Shinghar, I was led to expect that I should find a forest of dead or dying Chilgoza (*Pinus Gerardiana*) trees due to the ravages of the Borer Beetle. On arrival I was agreeably surprised to find that the forest was by no means in such a bad state as was represented.

There is no doubt that a large number of trees have suffered in the course of the last few years on account of the pest, but the proportion of green and healthy trees is still very considerable. Muhabbat Rai, the Forest Ranger lately appointed to the district, accompanied me and was at Shinghar through the whole season.

" On arrival I at once set about making a thorough inspection of the forest and carried out various experiments with antiseptics to ascertain which would be most efficacious in eradicating the pest.

" In past years the method of wholesale felling of affected trees had been adopted or failing this the application of coal tar to the bark. To my mind the former method was wasteful, as it precluded any chance of saving a partly affected tree.

" In addition to this I found that the Arozai and Haripal owners of the forest very strongly objected to the wholesale felling of their valuable trees. They are not sufficiently civilized to realise that the damage to the trees was done by boring beetles and argued that the forest had been their property for many generations and in all that time had come to no harm. They were incapable of believing that anything but 'Kismat' would kill the trees. In consequence they regarded with decided hostility any action which prematurely destroyed what appeared to them a healthy and fruit-bearing tree. I have all through the season taken the owners into my confidence, and attempted by optical demonstration to show them the real cause of the mischief. I believe that I have made some little impression on them, but they are very conservative in the matter. However, to induce their co-operation, I set myself to devise some method which would at any rate have the desired effect without killing partly affected trees. I found that coal tar smeared over the bark was useless as there were trees that had been previously so treated but had been lately attacked actually on the part where the coal tar still existed.

" It is not necessary to go fully into the methods and life history of the Shinghar Borers as they are given by Mr. Stebbing in his book entitled 'A Note on the Chilgoza (*Pinus Gerardiana*) Bark-boring Beetles of Zhob, Baluchistan.' It will suffice to say that the three borers (*Polygraphus Trenchi*, *Phlœosinus* and *Pityogenes coniferæ*) mentioned by him are all bark borers. Now the bark of the Chilgoza is very thin. It consequently struck me that probably some strong antiseptic could be used on the affected part of the tree which would soak in and kill the insects.

" With this in view I tried solutions of—

Perchloride of Mercury (1 in 300 and 1 in 500)—

1. Carbolic acid (1 in 20),
2. Kerosine oil alone,

3. Kerosine oil mixed with soap and water,
4. Slaked lime, and
5. Coal tar.

They were all, however, useless except kerosine oil. This was found to act on the beetle and kill it but was useless as regards the larvæ.

"Finally a mixture of coal tar and kerosine oil was smeared over the affected part and lighted. This made a hot and rapid flame, which heated the bark to such an extent that it killed both the beetles and larvæ entirely without apparently charring the tree. The affected part of the bark would be already ruined by the beetles, so the remedy could not damage the tree any further, whereas it effectually exterminated the insects. The treatment was received with delight by the owners as they saw a chance of gathering the nuts of many trees which otherwise would have been felled.

"After arriving at the above conclusion I had the whole of the Shinghar forest, both new and old, systematically examined, tree by tree. Those found healthy were blazed as an indication that they had been examined. The trees partly affected and still green were treated with tar and kerosine oil and trees past bearing were felled and burnt; altogether 1,643 acres of forest were gone over, which is practically the whole of it, both demarcated or otherwise.

"The curious feature of the Borer Beetles noticed this season was the very small proportion of new trees attacked by them. Out of the whole forest only one small sapling was found to have been attacked for the first time this year. I should say rather that this was the only one which the beetles had been able to bore into and breed in the bark. There were many instances where a swarm had settled on the bark and had attempted to bore as was evinced by small globules of sap or resin exuding from the bark, and in some cases the beetles were even found embedded in the globule. But no damage was done to the tree. On the other hand the trees that had been previously attacked and which were at all sickly or weak were found to be again infested in a new part with both beetles and larvæ.

"From the above observations, I have come to the conclusion that the Chilgoza tree, if healthy and full of sap, is able to protect itself against the onslaughts of the beetles, and does so by exuding resin as soon as the beetles prick its bark in trying to bore. This has the effect of either driving the insect away, or of drowning it, should it persist. It will be borne in mind that for several years prior to 1906 there had been severe droughts in Zhob. In consequence the Chilgoza trees had not been able to obtain sufficient nourishment and had lost vitality. They were, therefore, unable to resist the attacks of the beetles, not having sufficient sap to

exude. When Mr. Stebbing came to visit the forest, the drought had been severe and the pests were fast getting the upper hand. If the drought had continued, I have little doubt that the whole of the forest would have been killed off by the insects as predicted by Mr. Stebbing. But both last year and this there has been a good rainfall, with the result that the trees have regained their sap and vitality and are now able to resist the enemy should they not have been already attacked.

"However, I am confident that the resisting powers of the trees themselves and this year's campaign have almost exterminated the insects. Should next season be favourable they should disappear entirely. If not, I would strongly recommend that the trees be frequently inspected during the summer months and when a new one is attacked it should be at once treated with kerosine oil and tar.

"I repeatedly tried to get those owners of the Chilgoza trees who had not emigrated to Independent Territory to themselves co-operate with the Forest Staff and help in the campaign against the pest. But I failed to enlist their help without payment. I even held out hopes to them that their grazing rights would be restored should they co-operate without payment, but they were obdurate. The reason for their disinclination in the matter was that only a small number of actual owners of trees were present. The majority had emigrated when the bulk of the Arozais went across the border and the minority did not feel inclined to take upon themselves the responsibilities and work of the majority. Again, the short time that the Political Agent is at Shinghar is a time of golden harvest to this minority. There is plenty of demand for labour for building purposes, and forage and supplies are brought in, for all of which they are handsomely paid. They, therefore, did not feel inclined to forego the certain profits to be made, and give their services free in a cause in which they had not much faith or sympathy. I was therefore constrained finally to employ the local people on a daily wage to carry out the systematic eradication of the insects.

"Altogether, as stated above, 1,643 acres of forest were gone over; out of this 54 trees were treated with coal tar and kerosine oil and 217 were burned. The expenditure incurred in this treatment, including experiments, was Rs. 130-12-5.

"Mr. Stebbing, in his book, mentions three varieties of Boring Beetle at Shinghar, *viz.*, *Polygraphus Trenchi*, *Phlœosinus* and *Pityogenes coniferæ*. This season, I believe, a fourth species not mentioned by Mr Stebbing, has been discovered. The (larva) beetle is much longer and thicker than the other species, being about $\frac{1}{2}$ to $\frac{3}{8}''$ in length without its antennæ and of a dark brown colour. I secured two specimens of both beetle and larvæ, which have been sent to the Forest Extra Assistant Conservator. He has been asked to give any information about them

that he can and then to send them to the Quetta Museum. This species is far more destructive than the borer. It appears to attack dry trees as well as green ones, and in the latter the larvæ were invariably found among those of the *Polygraphus Trenchi.* In dry trees they leave a clear cut hole extending far into the wood which looks as if a rook rifle bullet had been fired into it. The Forester was unable this season to watch the life history of the insect as his time was fully occupied in other work. But next year he should make a special study of it. In some parts of the forest there are large numbers of old holes made by this species but not many living specimens were found. They were, however, discovered in both old and new Shinghar."

The above note on the position of the Shinghar Forest at the end of 1907 is one of great value since it is only by constant systematic and consecutive observation that it will be possible to really understand the periodic attacks of these bark-boring pests. That the long drought had, as Captain James suggests, a considerable influence upon the increase of the beetles in the forest is extremely probable. It is, however, by no means so certain that the cessation of this drought would have been followed by a diminution of the beetle attacks. Once a pest of this particularly destructive family of beetles has obtained the upper hand in a forest to the degree it had secured at Shinghar in 1905, if unchecked, the disappearance of the forest may be looked for as an almost foregone conclusion. I am of opinion that the state of affairs observed by Captain James during 1907 was a direct result of the steps taken by Lieutenant-Colonel Chevenix-Trench and Bhai Sadhu Singh in 1905-06, aided doubtless by the re-occurrence of the rains. The wholesale felling was a regrettable necessity rendered imperative by the very natural failure, in the absence of any knowledge on the subject of the life histories of the pests in question, to realize in time what was taking place in the forest. The heavy fellings in the avenues in Quetta were rendered necessary for just such a similar reason.* The objections of the Arozai and Haripal owners of the forests were foreseen at the time the remedy was prescribed, but as the alternative to be faced was the complete disappearance of the forest it was thought better, in the interests of the owners themselves, to whom the attack on the trees was practically demonstrated in June 1905, to take the one step which would have the best chance of checking the beetles.

The method of smearing coal tar and kerosine over the bark and setting it alight devised by Captain James is somewhat drastic but it is apparently effective. I should doubt, however, its being necessary since from his account the beetles would appear to have been reduced to the numbers ordinarily present in the forest. It is important, however,

* *Vide* my Note on the Quetta-Borer (*Æolesthes sartus*), Forest Bulletin No. 2, 1905, Government of India Press, Calcutta.

that the trees so treated should be examined during the summer of 1908 to see whether the bark gradually dries outward from the burnt portion. If this is the case it will most probably be found that the beetles will choose these spots to deposit their eggs during 1908.

In examining the forest for infested trees Captain James alludes to the fact that all trees found healthy were 'blazed.' This was a most unfortunate method of marking them since bark beetles invariably seek out wounds on trees in the neighbourhood of which to lay their eggs in preference to boring straight through uninjured bark.

I would suggest that if possible during 1908 the neighbouring forests of Sherghali and Spiraghar should be systematically examined for the pest as the excellent work carried out at Shinghar will be of little use if neighbouring infected centres are left untreated.

The fourth species of beetle alluded to by Captain James, of which specimens have been sent to me, consists of a species of longicorn beetle, family *Cerambycidæ.* The larvæ of this beetle tunnel both into the bast layer of the tree and into the timber. A member of the family, *Æolesthes sartus*, is the now well-known Quetta Borer, whilst another, *Batocera rubus*, is a pest of the fig tree in Baluchistan.

The exact danger of this beetle, a species of the genus *Stromatium* closely allied to *Stromatium barbatum*, to the Chilgoza Forests of Zhob has yet to be ascertained. I saw evidences of its attacks during my visit to the forest and obtained larvæ, but in the absence of beetles the determination of the insect was impossible. I may remark, however, that these longicorn beetles follow in the wake of the Scolytid bark borers and in all probability usually only lay their eggs in trees already successfully attacked by the *Polygraphus* beetle and its companions. Thus whilst they doubtless assist to some extent in killing the tree, they cannot be considered as either the originator of the attack upon it or as the direct cause of its death. I shall trust to deal with this insect in a subsequent note when further observations on its life history have been made.

A Note on the Present Position and Future Prospects of the Cutch Trade in Burma.

By R. S. TROUP, F.C.H.,
Imperial Forest Economist.

Recent drop in the quantity and value of cutch exported.—Some apprehension has of late been caused by a marked decrease in the quantity and value of cutch * exported from Burma during recent years, for which various reasons have been assigned, and as a result of a detailed enquiry which I have recently had occasion to make in the matter, it may be of interest to consider the facts elicited, particularly as to their bearing on the probable future of the cutch trade. A glance at the figures in appendix A will show that the net export value of Burma cutch is now considerably less than it was 10 to 15 years ago; it reached a very low figure in 1904-05, but has recovered slightly since then. The coasting trade, on the other hand, does not show the same marked tendency to decline in net value, though the quantity now handled is much less than it was formerly.

Drop in local prices.—The local up-country prices of cutch have also shown a serious decline. Thus at Pakokku, one of the local centres of the cutch trade in Upper-Burma, cutch sold a few years ago at R50 per 100 viss,† whereas of late the price has dropped to R25—R30.

Temporary fluctuations in the value of cutch have been of frequent occurrence in the past, and are bound to continue so long as the supplies fluctuate so much as they have done and still continue to do. This is

* Cutch is a brownish coloured extract obtained by boiling chips of the heartwood of *Acacia Catechu*, Willd. (including two varieties, *A. catechuoides*, Benth., and *A. Sundra*, *DC.*) The liquor obtained by the boiling is further boiled down to the consistency of syrup, poured into moulds, and allowed to harden. The valuable constituents of cutch are a tannin and a crystalline substance known as catechin, and the value of cutch as a tanning and dyeing agent depends on the amount of these two substances.

† 1 viss = 3·65 lbs. avoirdupois.

inevitable, because there is but a limited consumption of cutch, and any production exceeding this amount is followed, as a matter of course, by a decline in price. The permanent decline observed for years past is a more serious matter.

Money sunk in cutch plantations and reserves.—Any tendency towards a permanent decline in the cutch trade is a matter which closely concerns Government interests. Up to 1907 cutch plantations aggregating 8,656 acres have been created and maintained at a total cost, to date, of R1,46,044, in addition to which 6,696 acres of mixed teak and cutch plantations have been formed and maintained at a total cost, to date, of R1,00,437: charging half of the latter sum to cutch, it will be seen that about 2 lakhs of rupees have already been spent on cutch plantations.

Besides this, considerable sums have been spent in forming and maintaining natural reserves of cutch forests, so that any permanent decline in or total cessation of the cutch trade will be a matter of grave concern.

Factors which may account for the decline in the cutch trade.—Several reasons have been suggested to account for the decline in the cutch trade. Some of these are of little value, but there are three factors which are worth examining in some detail, and as will be seen below, the true reasons for the decline in the trade are to be found in a combination of three factors, which are—(1) the limited uses and demand for cutch, (2) substitutes for cutch, (3) adulteration and faulty manufacture.

(*1*) *Limited uses and demand for cutch.*—Owing to the introduction of cheaper substitutes, the quantity of Burma cutch now consumed is considerably less than it was some years ago. The world's annual consumption of Burma cutch probably does not now exceed 4,500 tons per annum, and when this demand is satisfied there is no other outlet for cutch. Moreover, the price must be a low one to tempt importers to purchase in anticipation of future requirements, as the cost of keeping cutch in store in Great Britain, and the loss in weight during about six months, adds some 10 per cent. to importing prices. As the speculative value of cutch is thus a low one, and as the quantity of cutch manufactured fluctuates a good deal year by year, the market prices of the product must, in view of the restricted demand, also fluctuate proportionally, and this fact explains to a great extent the ups and downs of the cutch market at comparatively short intervals, though it does not entirely explain the drop which has taken place for a long series of years; the latter drop is

due rather to the introduction of cheaper substitutes, and to the extensive adulteration which took place some years ago. Cutch is now used chiefly for curing or preserving fishing nets, and sails, the object of cutching nets being to prevent them from heating, and if they do heat, to prevent the heat from rotting the fabric. Dyers have almost entirely discarded cutch for aniline substitutes.

(2) *Substitutes for cutch.*—The chief products which have severely competed with Burma cutch are mangrove cutch from Borneo and elsewhere, and aniline dyes.

Mangrove cutch.—It is believed to be some 20 years since mangrove cutch was first introduced to the fishing industry in Great Britain, but it was not till 1898, as the result of very extensive advertising, that it was used to any great extent. It has also gained a footing in Holland during the past few years, but is not very largely used. Few fishermen use mangrove cutch alone; some will not use it at all, while others use a proportion mixed with Burma cutch. Mangrove cutch is obtained at a considerably lower price than Burma cutch, and is less liable to fluctuations in price. Although as a preserving material for fishing nets it is inferior to Burma cutch, still it finds favour to some extent because it dissolves readily and gives a red solution without any residue. As mangrove cutch does part of the work for which Burma cutch is used, it affects principally the cheaper qualities of the latter, and lessens the consumption of the cheaper grades of Burma cutch. For this reason it is most advisable to keep the standard of Burma cutch at the highest possible level. Mangrove cutch is manufactured from the bark of mangroves, the chief of which are *Ceriops Candolleana* and *Rhizophora* spp. The trade in this cutch in the Straits is an extensive one, the amount passing through Singapore alone being over 20,000 cwt. annually. The imports into Singapore are from Borneo, Labuan, Sarawak and other localities, not from the Federated Malay States, whilst the imports into Penang are mostly from Sumatra. A large proportion of the mangrove cutch imported into Singapore is used locally and not exported.

The Divisional Forest Officer, Rangoon Division, reports a local manufacture of mangrove extract which is not exported but is used locally for curing fishing nets and sails; a similar extract is prepared in Arakan.

Analysis of mangrove cutch.—A sample of mangrove cutch received from the Straits was subjected to analysis by Mr. Puran Singh, Acting

Imperial Forest Chemist, who reports on it as follows :—

" The sample of mangrove cutch shows little resemblance with cutches of Acacia and Gambier. It does not answer the general tests for cutches. It is entirely soluble in cold water, while good cutch is almost entirely insoluble in cold water. It has no crystalline principle like catechin and appears to be a sort of tannic acid which in dilute solutions gives a very dirty green colour with a dilute solution of ferric chloride, while catechu-tannin gives in dilute solutions a fine green colour. It has been tried by Messrs. R. B. Brown and Hummel for dyeing and they report on it favourably as a dyeing agent. I cull the following remarks from the reports of the Imperial Institute, London, for the year 1903 :—

" ' The Mangrove Cutch behaved during the dyeing process very similarly to the Bull-cutch, the chief difference being that in the first operation the cotton is stained a very much more reddish-shade than that given by any other cutch examined. These dyeing experiments show that the Bull and the Mangrove cutches may be considered as belonging to group II, indeed they may be placed at the head of this class, since after twice dyeing they give much darker colours than any of the rest.'

" As a tanning agent it is not so favourable as it produces very inferior leather of red colour. However, it is very much recommended for producing sole leather as the latter tanned by it is comparatively more tight and durable."

Aniline dyes.—Dyers have now almost ceased using cutch in favour of aniline colours, and it is only the continued development of the fishing industry which has saved the cutch trade from extinction. The following extract, from the journal of the Society of Chemical Industry, affords information on the subject :—

" Catechu ; Substitutes for—, and their application in Calico Printing. G. Grieder, Färber Zeit. 1901, 12, (1), 7—9. Catechu, which was formerly largely employed in dyeing and printing of cotton fabrics, has been largely replaced in the former industry by these substantive colours, which acquire the requisite fastness by an after treatment with metallic salts, or by coupling with diazotised paranitraniline. In calico printing it has been superseded by alizarins or other colours which are fixed by metallic oxides on steaming. In the printing of hosiery fabrics, such as flannelette, it is still employed to a considerable extent in Russia, Italy, Germany and Austria, on account of its cheapness and fastness.

"One of the chief defects of catechu is the tendency of the prepared colour to undergo oxidation before it is used for printing, owing to the combined action of the air and the copper sulphate present in the colour. A finely divided precipitate is thus produced, rendering the colour gritty and unfit for use. Catechu printing colours which have not been sufficiently boiled, or do not contain sufficient acetic acid, are liable to deposit crystalline catechin, with the same result as above. The oxidising agents used for developing the colour are also liable to bring about tendering of the fibre, especially if chlorates are employed. These and other defects have led many printers to seek for satisfactory substitutes. Among those of recent introduction are Fast Brown J. A. and Fast Brown R. S. (A. Huillard), which are apparently prepared from natural dyestuffs, and have the same defects as catechu. Another substitute is catechu Brown O. S. C. (O. Starcke and Co.); this yields smooth and stable printing colours, and the shade can be varied at will by the addition of colouring matters capable of being fixed with chromium acetate, this being the only substance necessary to be added to the thickened colour.

"Printing Brown P. M. B. (P. and M. Bohme) greatly resembles the colour just described, and yields shades which are fast to washing and to acids.—R. B. B."

(3) *Adulteration and faulty manufacture.*—Enquiries have been addressed to many of the leading cutch importers and users, and their unanimous opinion is that the quality of cutch manufactured now-a-days is superior to what it was some years ago, when adulteration was freely practised on a large scale. There can be no doubt that this adulteration did a great deal of permanent harm to the cutch trade, which can never hope to regain what it has lost, as this adulteration was one of the primary causes which led dyers to forsake cutch for aniline substitutes. The chief fault to be found with the cutch now manufactured is that some of it contains an undue amount of moisture. It has frequently been suggested that cutch, though it may be pure when it leaves the manufacturer's hands, is often subject to adulteration by the brokers through whose hands it passes. To test the accuracy of this statement, samples of cutch were obtained from cutch-boilers' camps and from the brokers' warehouses in Rangoon and subjected to chemical analysis. In each case the samples were taken haphazard from the stocks in hand. The results of the analysis are given in Appendix B. As the total number of samples received was

only six, these results can hardly be taken to prove very much, but as far as they go they give no indication that the cutch is adulterated by the Rangoon brokers before shipment; on the other hand, the inferiority of the sample from Prome indicates that in that particular instance adulteration had taken place during manufacture. There is undoubtedly room for improvement in the manufacture of cutch, whereby the proportion of soft cutch may be reduced to a minimum.

Effect of the new cutch rules.—Prior to the 1st October, 1904, Government revenue on cutch was collected by the issue of licenses at fixed rates per cauldron of given capacity used in the boiling of cutch. Such licenses were applicable only to cutch trees growing on public land, no licenses being required and no duty being leviable in the case of trees cut on tenanted land. As this system was productive of much abuse on the part of cutch boilers, who habitually stole trees on public land in order to remove and convert them on their own holdings, it was resolved to levy an export duty, at the port of shipment, on all cutch manufactured in Burma and exported by sea. The new system was introduced on the 1st October, 1904, the export duty being fixed at ₨4 per 100 viss, which is equivalent to 365 lbs. avoirdupois. Licenses for boiling cutch are still issued, but no payment is required for these licenses when issued in areas outside reserved forests. The chief object of issuing these free licenses is to prevent the extermination of cutch trees on lands which are likely to be constituted reserved forests. The direct effect of the new cutch rules will be the rapid extinction of cutch trees on lands not included in reserved forests and on lands the reservation of which is not contemplated. Even under the old system of prepaid licenses the extinction of cutch trees on such lands would have been merely a matter of time, as the large areas to be patrolled and the numerical weakness of the forest staff would have militated against any systematic protection of cutch trees, while at the same time Government would have been deprived of a large proportion of its legitimate revenue. From the foregoing remarks it will be seen that at the present time cutch trees outside reserved forests are undergoing the process of rapid extinction; this is inevitable, and it would have been inevitable under the old rules also. In some localities cutch boiling is an extinct industry, and in others it will soon be so. Against this, however, is to be weighed the fact that there are large stocks of natural cutch trees within reserved forests; these have in many reserves

been left untouched for years, and will afford a permanent future supply. In addition to this many of the cutch plantations are approaching maturity, and will still further ensure a regular yield of cutch.

Future supplies of cutch.—It is impossible with data at present to hand to form anything like an accurate estimate of the annual yield of cutch which is likely to be afforded when the present stock of trees outside reserves has become exhausted. Whatever the actual future supplies may be, however, they will at all events be far more regular and less fluctuating when the reserves come to be worked under fixed working-plans than they have been in the past or are likely to be during the next few years.

The depletion of cutch trees as affecting the local population.—The depletion of cutch trees in unclassed forests is likely to produce distress in the poorer districts where cutch boilers cannot find employment in reserved forests. The manufacture of cutch is carried out chiefly in the drier parts of Burma, where cultivation is not always in a flourishing state, and where a certain proportion of the people resort to cutch boiling as a means of livelihood. Where cutch reserves exist in sufficient extent, however, there should be no distress if these forests are in a condition to be worked under regular working-plans. Another adverse effect of the depletion of cutch trees will be the loss to the cultivator of the wood which supplies him with his harrow teeth.

Catechin-free cutch.—A few years ago experiments with cutch were made at the Imperial Institute, London, and the results are embodied in the Imperial Institute Technical Reports and Scientific Papers of 1903, on page 229 of which the following passage appears:—"Since catechu-tannic acid possesses greater colouring power than catechu, it is evident that the cutches which are more lustrous, more soluble, and richer in catechu-tannic acid are the most valuable for the purpose of dyeing cotton."

In the hope that a manufactured form of cutch containing no catechu might prove of value, samples of catechin-free cutch were recently prepared at the laboratory of the Imperial Forest Chemist, Dehra Dun, and were sent for trial to Great Britain. They were, however, found to possess no special advantage, either for dyeing or for curing fishing nets, and in this connection it is of interest to quote the views of a well-known British firm on the subject:—"For our part we consider catechu a valuable

property in Burma cutch, when cutch is used for curing or preserving herring nets. We understand when cutch liquor is cold, it is the catechin which forms a sort of limey deposit. Some fishermen object to this limey substance on their nets, but those of greater experience recognise that when the nets are covered with this limey appearance, these are the nets which after being in the sea prove to be the best cured. The nets may be drawn out of the cold liquor covered with this limey substance and, so far as colour is concerned, with little appearance of having been in cutch, but after a few trips to sea, the colour develops to almost jet black, a sure sign that the nets have been well cured. Consequently, our convinced opinion is that catechin in Burma cutch is a valuable property when the cutch is to be used for preserving herring nets, and makes Burma cutch of greater value than cutch made from Mangrove, Hemlock, etc."

Future prospects, and measures recommended.—It is impossible to foretell with any accuracy what the future of the cutch trade will be, but as far as present indications go it is probable that the price of cutch will find a still lower permanent level. In any case extensive adulteration or faulty manufacture will mean the doom of the cutch trade, for whereas high grade cutch finds a ready market, inferior cutch cannot compete with cheaper substitutes. It will further be of advantage to keep the supplies of cutch as regular as possible; this cannot be done with any certainty for some few years yet, but when reserved forests come to be systematically worked the supplies of cutch should be fairly regular.

The chief measures necessary for the future maintenance of the cutch trade in Burma are (1) to prevent adulteration and faulty manufacture, and to keep the standard of cutch as high as possible, and (2) to avoid any hiatus in the production of cutch between the time when the cutch trees are depleted outside reserves and the time when they come to be regularly worked within reserves; for this reason it is highly desirable that all workable cutch areas within reserves should in good time be brought under the provisions of working-plans in those localities where the trees outside reserves are approaching extermination.

APPENDIX A.

Statement showing the quantity of cutch exported from Burma during the years 1894-95 to 1906-07.

Year.	Foreign.			Coasting.			Total.			Remarks.
	Quantity.	Value.	Per	Quantity.	Value.	Per	Quantity.	Value.	Per	
	Tons.	R	Ton.	Tons.	R	Ton.	Tons.	R	Ton.	
1894-95	5,524	22,34,516	404	3,989	14,95,102	374	9,513	37,29,618	392	
1895-96	7,827	33,52,484	428	3,333	13,06,637	392	11,160	46,59,121	417	
1896-97	5,853	22,90,365	391	1,620	6,32,916	390	7,473	29,23,281	391	
1897-98	4,821	18,58,752	385	614	2,30,291	375	5,435	20,89,043	384	
1898-99	3,075	12,77,985	415	655	3,06,521	467	3,730	15,84,506	424	
1899-1900	6,302	24,34,101	386	1,159	5,76,171	497	7,461	30,10,272	403	
1900-01	4,949	18,42,063	372	1,102	5,30,730	481	6,051	23,72,793	392	
1901-02	3,273	11,94,898	365	770	3,21,237	417	4,043	15,16,135	375	
1902-03	3,460	13,18,921	381	953	4,20,208	440	4,413	17,39,129	394	
1903-04	5,492	19,11,943	348	1,322	5,36,387	405	6,814	24,48,330	359	
1904-05	3,018	9,31,596	308	779	3,12,749	401	3,797	12,44,345	327	
1905-06	2,723	8,48,887	311	755	3,59,069	475	3,478	12,07,956	347	
1906-07	4,772	15,53,470	325	868	3,61,905	417	5,640	19,15,375	339	

APPENDIX B.

Note on the analysis of six samples of Burma Cutch by MR. PURAN SINGH, *Acting Imperial Forest Chemist, Dehra Dun, 9th September 1907.*

I BEG to submit herewith the chemical analysis of 6 samples of Burma Cutch sent by you to my office.

It will be seen from the table given below that some of them are very moist; 11—13 per cent. I think should be the limit of total moisture in a good sample of cutch. No. 2 and No. 3 exceed this limit by 5 and 8 per cent., while No. 4 and No. 6 by as much as 21—25 per cent. The sample of cutch I extracted from Acacia wood in my laboratory shows an average of 12·965 per cent. of moisture.

Argued from the percentage of ash residue the sample No. 2 is very impure. The normal limit of ash is given at 5 per cent., and the percentage of ash in sample No. 2 exceeds this limit by 10 and the samples No. 3 and No. 4 by 2 per cent.

The catechin value of these samples is generally good excepting that of No. 2, which comes only to 5·2 per cent. The method adopted for the determination of catechin is one of my own and the relative merits of this process and that already known by acetic ether extraction, I am to discuss in a separate pamphlet on the subject.

But I may note here in passing that the catechin value found by me is higher than that found generally by the acetic ether process, as in the latter the complete isolation and extraction of catechin does not take place as believed, for pure catechin goes with ether rather reluctantly while in the menstruem used by me it dissolves with extreme ease.

The tannin value of these samples is also fairly good, excepting that of the second sample, which is only 21·2 per cent. The percentage of insoluble organic matter is within its limit in all these samples excepting that of the second, which runs up to 25 per cent.

On the whole I find that excepting samples No. 2 and No. 6 all the samples are good. No. 2 is very deficient in tannin value, while No. 6 is very moist and its tannin value is, comparatively, very low.

Laboratory No.	Whence received.	General description.	Water.	Ash.	Catechin.	Tannin.	Non-tanning solids.	Insoluble organic matter.	Spirit extract.	REMARKS.
			Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	
1	Deputy Conservator of Forests, Lower Chindwin Division, Upper Burma (straight from manufacturer).	In large cakes, solid. brittle, dark brown; in powder whitish gray.	11·110	2·195	29·2	54·5	2·862	0·133	59·7	Very good.
2	Deputy Conservator of Forests, Prome Division, Burma (straight from manufacturer).	Dark red compact mass, red in powder.	16·825	15·065	5·2	21·2	17·6	24·11	19·3	Bad.
3	Tablet cutch from Rangoon Broker, received from the Conservator of Forests, Pegu Circle, Rangoon.	Dark, elastic, unpulverisable.	19·59	7·35	13·6	49·0	...	1·57	51·80	Good.
4	Block cutch from Rangoon Broker, received from the Conservator of Forests, Pegu Circle, Rangoon.	Dark brown, liquid extract consistence.	32·06	3·095	25·01	57·3	...	0·727	55·8	Very good.
5	Divisional Forest Officer, Mu Division. Upper Burma (straight from manufacturer).	Square blocks, brick red colour at surface. reddish brown in the centre, hard, brittle, reddish brown when powdered.	12·305	2·69	24·2	39·0	21·413	0·362	55·4	Good.
6	Soft cutch from Rangoon Broker, received from the Conservator of Forests, Pegu Circle, Rangoon.	Dark colour, semi-fluid mass of honey consistence.	36·665	2·13	24·1	24·0	12·045	1·06	51·07	Fairly good, but too moist.

A Note on the Manufacture of Ngai Camphor from the Blumea balsamifera D. C. of Burma.

By PURAN SINGH, F. C. S.
Member of the Pharmaceutical and Chemical Societies of Japan
Acting Imperial Forest Chemist.

PRELIMINARY INFORMATION REGARDING NGAI CAMPHOR, ITS ORIGIN AND PREPARATION.

One of the earliest writers on the subject of the extraction of Ngai camphor was Dr. Mason. That the camphor is prepared in Southern Shan States and China from Blumea balsamifera D.C. was first recorded by him about the year 1883 in his "Burma, Volume II, *Botany*" in the following remarks :—

"One of the most abundant weeds throughout Burma is a species of Blumea that grows 6′ to 8′ high with leaves like Mullen, which when bruised emit a strong odour of camphor. Many years ago, the Tavoyers informed me that they were in the habit of making an impure camphor from the weed by a very simple process, but Mr. O'Riley was the first to make a good article from it and to bring it to public notice. He made more than a hundred pounds, and the specimens which he sent to Calcutta were reported : 'In its refined form it is identical in all its properties with Chinese camphor.' The plant is so abundant that Burma might supply half the world with camphor. Whenever the trees are cut down, this weed springs up and often to the exclusion of almost everything else ; so that an old clearing looks like a field under cultivation.

"The apparatus required for the distillation of camphor is extremely simple, consisting simply of a capacious vessel, wherein the material containing the camphor, cut up and mixed with water, is boiled ; and a head, consisting of one or more pots, to receive the products of distillation which is kept cool by means of wet cloths, receives the crude camphor deposited during the process of condensation. A re-distillation by dry heat of the crude camphor, produced by the first process, is all that is required to produce the refined article."

The next writers of importance to whom we are indebted for valuable contributions on our knowledge of the same subject were Hanbury and Dr. A. Henry, F.L.S. Here is a short note (quoted in the Kew Bulletin of November 1895 from Hooker's *Icones Plantarum*) from

Dr. Henry, a letter from whose pen, giving a detailed description of the process employed by the Chinese for the extraction of Ngai camphor, has been placed under liberal quotation further below :—"From this is produced in Kwangtung and Hainan the peculiar camphor known to the Chinese as *ngai-fên*, signifying the crude product, and *ngai-p'-ien*, the name given to the refined article. The export from the port of Hoihow in Hainan of the crude camphor is about 15,000 lbs. annually. This is refined in Canton, from which there is an annual export of about 10,000 lbs. of *ngai-p'-ien*. Hanbury (*Science Notes*, page 394) gives an account of the camphor, and mentions that the plant in question is well known to emit when bruised a strong odour of camphor, and that in Burma a crude camphor is extracted from it."

The Chinese engaged in the camphor industry, it is said, jealously guard as a secret the name of the camphor-yielding tree and also the process which they employ for the distillation of camphor. Mr. Gilman, a member of the American Presbyterian Mission, who was stationed in Kiungchow, the capital of Hainan, about the year 1892, was, however, able during his missionary journeys through the country to make careful enquiries into the details of the manufacturing process and to see for himself the natives extracting the article. His account of the process is given in the following extracts from Dr. Henry's letter[1] to the authorities of the Kew Royal Gardens, which has been referred to above :—

" 'Some time ago Mr. Ridley, of Singapore, asked me to find out the details of the process, employed by the Chinese in Hainan, for the extraction of *Ai* camphor from *Blumea balsamifera* D.C. He had tried to obtain the camphor by distillation from the leaves of the plant, but had only succeeded in getting an oil. Through the kind offices of Mr. Unwin of the Chinese Customs at Hoihow, I have received the following interesting account of the process from the Rev. F. P. Gilman, and I send it to you for insertion in the Kew Bulletin. . . . .

" ' The plant is in flower in July and August. During the fall and winter months the Chinese of the island or the aboriginal Lois in Chinese employ collect the young leaves of the plant, which there grows to a height of 8 or 10 feet. They say they only take the last three joints of the branch, as in the specimens which I have collected. These leaves are allowed to remain on the branch, and are wilted for a couple of days. They are then placed in the retort, which is a cask about two feet high, open at both ends, and of a diameter suitable to place it over a large

[1] Published in Kew Bulletin, No. 107, November 1895, pp. 275—276.

Chinese frying pan (say, the diameter is 20 inches). The frying pan is filled with water, and over the water is placed a coarse sieve of woven bamboo to separate the leaves from the water. The cask is cemented with clay to the edge of the pan, and after receiving its charge of 30 lbs. or 40 lbs. of the leaves, a large brass basin is placed on the upper open end of the cask, and is filled with cold water, which is frequently changed. Fire is placed under the frying pan, and the process of distillation is continued for about four hours. At the end of that time the brass pan is lifted off, and its lower surface is found to be coated with a layer of crystallized substance about a sixteenth of an inch thick. This is the *gnia-hūn* (local dialect for *ai-fên*), or crude camphor, which Mr. Unwin, the Commissioner, tells me is sent to Canton and re-manufactured into *ai-p'-ien* or refined camphor.'

"I enclose Mr. Gilman's specimen (of the leaves of the plant from which he was told the camphor was distilled by the Chinese), which is not *Blumea balsamifera*, but, as well as I can make out from a cursory examination, is probably a species of *Buddleia*. There are no flowers, only leaves, and the latter have no camphoraceous odour when bruised. I am inclined to think that Mr. Gilman has been deceived as to the plant, and that the Chinese substituted the leaves of another plant for the one actually employed. I am inclined to think that *Blumea balsamifera* is the true source. The leaves of the *Blumea* have a certain rude similarity to those sent by Mr. Gilman.

"The authority for Blumea as the source of this peculiar camphor rests on Hanbury, *Science Papers*, page 394 . . . ."

The above accounts of the method of the Ngai camphor manufacture practically tell all that is known regarding it. It may be of interest, however, to give here the most recent account available of the manufacture of Ngai camphor. The interesting and valuable information given below is from the pen of the Assistant Political Officer stationed at Kenglung, who, in a letter communicated to the Forest Department, Burma, in the year 1905, advocates the importance of undertaking an investigation into the subject of camphor distillation in Burma to settle the question as to whether a profitable Ngai camphor industry could be organised in that province. The said Political Officer, after mentioning that a considerable industry of camphor extraction is carried on in Kenglung from where the article is exported to the Southern Shan States, gives the following account of the camphor and its preparation :—

"Camphor, which is an article of considerable export from this State, is largely produced in the Mong Hai district of the State of Keng Hang

(Chinese territory), where the average annual output is between four to five thousand *vis*. The trees also grow in Keng Heng State (Mong Nyen district), but the method of extraction is imperfectly known. An attempt is being made to get a few men from Mong Hai to teach the villagers of Mong Nyen.

"In Mong Hai the leaves of the trees are placed in a bamboo woven cylinder supported by bamboo batons a few inches from the bottom. The cylinder is placed in a cauldron filled with water which is kept boiling. On the top of the cylinder rests a similar cauldron filled with cold water, which is baled out frequently and replenished so as to keep the temperature as low as possible. The steam rising through the leaves condenses in the cold cauldron and leaves the camphor crystals on the bottom of the same. The deposits are removed three or four times a day and the article of commerce exported through Keng Heng to Burma." (See Plate II.)

Review of the above and a proposal to manufacture Ngai Camphor in Burma.

It will be seen that the descriptions by different writers given in the last chapter of the Chinese method of manufacturing the *ngai* camphor are almost identical, as regards the principle and the details of the process. It appears that the camphor industry in Hainan does not rest on any scientific and organised basis, and to manufacture the small quantity of the camphor (40—50 lbs. a day), which Hainan produces, the people have to go through an amount of trouble and labour quite disproportionate to the value of the meagre quantity produced. This is one among many illustrations of the fact that the Asiatic is of an intensely conservative cast of mind, for, were it not the case and were the people enterprising, a single individual with the aid of a capacious efficient still could turn out in a single day the quantity of the camphor which the whole of Hainan produces in the same time. It is thus clear that an attempt to investigate the subject of camphor distillation with a view to improve the method of manufacture is of vast industrial importance.

There exists no doubt now as to the identity of the plant from which the Chinese manufacturer extracts the *ngai* camphor. This plant, known to the botanist as *Blumea balsamifera*, has been known to grow more abundantly in Burma than elsewhere, and if the Chinese can manufacture camphor from it, there appears no reason why its abundance in Burma should not be utilized and an organised camphor industry started throughout the province. It should be mentioned here that Dr. Mason

is rather enthusiastic and over-sanguine in his forecast of the prospects of organising a camphor industry in Burma, for his statement, quoted in the opening paragraph of the last chapter, that Burma could supply from this particular source (*Blumea balsamifera*) half the world with camphor, appears to me to be unwarranted by the conditions under which a camphor manufactory would have to be run at the present day. No doubt the plant is very common in certain parts of Burma, but a factory requiring regular supplies of a few tons of this weed a month could not be kept working the whole year around, for a regular exploitation of the areas where it grows even very abundantly would exhaust the supply of the plant in a short time. A constant and regular supply of the raw material could not be maintained, unless we succeed in artificial cultivation of the plant; but this question of the artificial growth of Blumea balsamifera D.C., though of considerable interest and importance, has not, up to the present, received much attention. Thus a factory, as well as I can judge from enquiries made during my recent tour in Burma, depending upon the natural supply of the weed alone, could only be kept working from three to four months a year. But this fact notwithstanding, it is possible to make camphor distillation in Burma a profitable concern by judicious and intelligent action on the part of the Forest Department, even before we have successfully attacked the problem of the artificial cultivation of the camphor-yielding plant.

Up to this time nowhere in Burma, as erroneously mentioned by some of the writers quoted in the last chapter, has *ngai* camphor been manufactured on any scale from *Blumea balsamifera.* So far as I have been able to gather during my recent tour in Burma, it seems that the only use that the Burmans and the Shans make of the plant is as a medicine by making a decoction of it with boiling-hot water. This decoction is administered by the Burman physicians for female complaints, and for colds and headache. As already stated, the Chinese, it is believed, jealously guard as secrets the name of the camphor-yielding plant and some details of their distillation process; and the fact that Mr. Gilman was deceived by the Chinese as to the plant from which they extracted the camphor would appear to support this belief (*vide* Dr. A. Henry to Royal Gardens, Kew, *loc. cit.*, and also page 267 above). It is, therefore, most probable that although most of the information regarding the *ngai* camphor and its preparation, which has been collected from the Chinese and other sources, is definite and correct, there yet remain to be brought to light some minor but essential details which

appear to have been jealously kept back by the 'celestial' manufacturer. We are not told, for instance, if any oil is obtained as a by-product from the plant. Further, information is not available on the important points, whether the plant is subjected to some preliminary mechanical, chemical, or other treatment to obtain from it the maximum yield of the camphor; whether only *Blumea balsamifera* alone, or together with other camphor-yielding species, is utilized for camphor distillation; whether any substance is added to the still to facilitate the sublimation of camphor. Apart from the scientific interest attaching to them, the solution of these questions has a direct practical bearing on the expansion of the *ngai* camphor industry. It has not been possible to undertake a systematic investigation to elucidate these obscure points; but it may be noted here that in the course of a series of experiments made on the distillation of the Blumea balsamifera of Burma answers were incidentally obtained to some of these questions. These answers which appear to me to be more or less conclusive, will be dealt with later on.

The question of camphor distillation in Burma being of great economic importance, it has of late been occupying the attention of the Forest Department. Since the subject required to be investigated both in an economic and a chemical direction, it was submitted by the Chief Conservator of Forests, Burma, who took up the matter, to the Imperial Forest Research Institute. The first question was to design an experimental still of sufficient capacity to see if camphor could be manufactured on a commercial scale from the Blumea balsamifera D.C. of Burma. The next point that required a chemical investigation was to determine the total percentage of essential oil in the fresh green plant and to compare it with the percentage obtained from the plant in its dry state. These analytical determinations were made with the plants growing in the Taungoo and the Katha Divisions during my recent tour in Burma, undertaken with the permission of the Inspector General of Forests, with the object of investigating some important points connected with camphor distillation. Before the results of these analytical experiments and of the experimental distillation of the plant with the still referred to above are given, it is considered desirable, for a better understanding and appreciation of the results, to describe briefly the plant and the chemistry of *ngai* camphor (showing its relation with the common or Laurus camphor), together with the methods of plant analysis for moisture and volatile oil determinations.

BLUMEA BALSAMIFERA D.C.

B. balsamifera (Burmese, *Poung-ma-theing*) is an evergreen semi-shrub-like composite sometimes growing into a small tree.[1] It is woolly throughout, the leaves, which smell strongly of camphor, being thickly covered with silky villi or soft downy substance. The flower-heads are rather small and shortly pedunculated, forming large tomentose panicles, spreading or pyramidical in shape. The florets are numerous and yellow in colour. The pappus is soft, and red or pinkish pale-coloured.

Habitat.—The plant is indigenous to Eastern India and is found from the Himalayas to Singapore and in the Malay Archipelago. It also grows in South China and the islands Hainan and Formosa. It is found to grow very abundantly in Burma, where it freely springs up in deserted Toungyas or Poonzohs[2] and in other forest lands which are devoid or nearly devoid of trees.

Remarks.—The plant flourishes best in sunny exposures. Its flowering and fruiting time is the hot season. Its wood is the pale-coloured, soft, and exceedingly light, but with a close grain.

THE CHEMISTRY OF CAMPHOR.

It is not necessary to describe the chemistry of camphor in great detail, but a brief and general account of the most important facts regarding the composition and the properties of the three well-known varieties of camphor may usefully be given here.

Camphor in chemistry is a general term applied to a variety of oxygenized solid bodies all of vegetable origin and similar in their general characteristics. They are colourless, translucent, volatile substances of tough, waxy structure, and are generally extracted from what are called the *essential* oils. Of the numerous camphors or *stearoptenes*, as they are also designated, three only are objects of commerce. They are—(1) Laurus or common camphor, (2) Borneol or Borneo camphor, and (3) Blumea or Ngai camphor.

i. *Laurus camphor*, $C_{10}H_{16}O$.

This is the most important commercial form of camphor, and is

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[1] For a complete botanical description of the plant *vide* Kurz, *Forest Flora of British Burma*, II, p. 82; also Sir J. D. Hooker, *Flora of British India*, III, p. 270.

[2] Toungya Poonzoh or simply Poonzoh, meaning deserted culture-land, is the name given to large tracts of forests which have been deserted after having been felled and utilized for two or three years for rice cultivation by the Burmese.

obtained as a crystalline substance by extraction with water or by steam distillation from the wood of *Cinnamonum camphora*, the well-known camphor laurel of Japan and China. The product obtained by distillation is afterwards refined by sublimation.

Common camphor is a colourless semi-transparent substance of a granular and crystalline structure. It volatilizes readily at ordinary temperatures, emitting a peculiar penetrating aromatic odour. It has a bitter, pungent taste. Its specific gravity at 0°C. is 1·0, and 0·9853 at 18°C. It is but slightly soluble in water (1 in 1,200); and when thrown in small fragments on the surface of that liquid, displays peculiar gyratory movements, which, however, are not executed in the presence of even very small quantities of oil. Being of a tough and waxy structure it is very difficult to pulverize, but the pulverization is readily effected by means of a little alcohol or sugar, ether or choloform. It is readily soluble in organic solvents, *e.g.*, alcohol and ether.

It melts at 175°C., and boils and distils without change at 204°C. It is an inflammable substance, and burns with a smoky flame.

Common camphor is an optically active substance, its alcoholic solution turning the plane of polarisation to the right. On this account it is sometimes in scientific works referred to as d-camphor.[1]

Principal reactions of camphor.—(1) Camphor is very energetically acted upon by dehydrating agents such as phosphoric acid anhydride, sulphuric acid and zinc chloride. On heating with phosphoric acid anhydride, it is changed into a hydrocarbon called cymene or cymol by losing the elements of water, thus :

$$C_{10}H_{16}O = H_2O + C_{10}H_{14}$$

Camphor. Cymol.

Sulphuric acid and zinc chloride yield other substances along with cymol.

(2) Prolonged boiling of camphor with nitric acid results in the formation of camphoric acid $C_{10}H_{16}O_4$, thus :

$$2C_{10}H_{16}O + 3O_2 = 2C_{10}H_{16}O_4.$$

(3) Camphor absorbs gaseous hydrochloric acid, forming an oil from which it can be readily regenerated by decomposing it with water.

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1 In optics those substances which rotate the plane of polarisation to the right are called dextrogyrate or dextrorotatory; while those which turn it to the left are known as lævogyrate or lævorotatory. d-camphor means dextrogyrate camphor. Likewise, l-camphor = Lævogyrate camphor.

Nitric acid has no decomposing action on camphor in the cold, but forms with it an oily liquid from which camphor is precipitated on the addition of water.

(4) By acting on a solution of camphor in chloroform with bromine, a bromide of camphor $C_{10}H_{16}Br_2O$ is formed.

By the action of bromine on camphor alone at 100°—120°C, mono-brom-camphor $C_{10}H_{15}BrO$ and dibrom-camphor $C_{10}H_{14}Br_2O$ are formed. It will be seen that these are substitution products of camphor.

The bromide of camphor is an unstable substance which is spontaneously decomposed, especially under the influence of light, into mono-brom-camphor and hydrobromic acid.

$$C_{10}H_{16}OBr_2 = HBr + C_{10}H_{15}BrO$$

(5) By reduction with sodium, camphor is converted into Borneol or Borneo camphor (*q. v. infra*), which according to its chemical nature is an alcohol. The inverse reaction which is mentioned farther on can also be readily accomplished.

To understand the significance, from a theoretical point of view, of these two interesting reactions, standard works on organic chemistry should be consulted, but it may be noted here that the conclusions that are to be drawn from these two reactions are that borneol bears the same relation to camphor as an alcohol to its aldehyde or as a secondary alcohol to the corresponding ketone.

ii. *Borneol camphor* (*d-borneol*), $C_{10}H_{18}O$.

Borneo camphor, also called Barus camphor or Kapur Barus (from Barus, a town in Sumatra), Malay camphor, Sumatra camphor, and in India known as Bhimsaini or Baras, is extracted from *Dryobalanops camphora.* It has small colourless and friable crystals, which when the article is re-crystallised from ligroin are, according to Traube (*Journ. F. Prakt. Chem.*, Vol. II, 49, p. 3), brilliant laminæ or plates belonging to the hexagonal system.

Its odour is more or less similar to that of camphor, but is less pungent, and recalls at the same time the odour of pepper. It melts and boils at higher temperatures (m. p. 203°—204°C., b. p. 212°C.) than Laurus camphor, has greater specific gravity (according to Plowman, *Pharm. Journ.*, III, 4, p. 710, sp. gr. for d-borneol = 1·011, for l-borneol = 1·02), is

somewhat more brittle and less hard, is less volatile, and finally has, unlike common camphor, no great tendency to sublime spontaneously in the interior of the vessels in which it is kept.

Like ordinary camphor, it is insoluble in water, but dissolves readily in alcohol and in ether. It turns the plane of polarisation to the right, and for that reason is sometimes referred to as d-borneol.

Reactions of Borneo camphor.—By heating with phosphoric acid anhydride (P_2O_5), borneol is changed into a hydrocarbon, called Borneen, by the dehydrating action of P_2O_5, thus :

$$\underset{\text{Borneo camphor.}}{C_{10}H_{18}O} = H_2O + \underset{\text{Borneen or Borneo camphene.}}{C_{10}H_{16}}$$

Towards zinc chloride and dilute sulphuric acid it is very stable.

Nitric acid as oxidising agent changes Borneo camphor first into Laurus camphor and further into the oxidation products of camphor like camphoric acid, campholic acid, etc.

By the action of bromine and hydro-halogens on borneol unstable additive products are formed.

Borneol, as has already been stated, may be regarded as a secondary alcohol. As such, it is changed by oxidation into the ketone, $C_{10}H_{16}O$, which is camphor and which is optically active always in the same direction as the borneol from which it is produced.

$$\underset{\text{Borneol.}}{2C_{10}H_{18}O} + O_2 = \underset{\text{Camphor}}{2C_{10}H_{16}O} + 2H_2O$$

Berthelot obtained borneol by heating ordinary camphor for a long time with an alcoholic solution of caustic potash. It can also be readily obtained from d- or l-camphor by reduction with sodium in alcoholic solution or in indifferent solvents, but thus prepared borneol is never pure but is mixed up with iso-borneol.

The most important ester of borneol is Bornyl acetate, which occurs very commonly in volatile oils.

iii. *Blumea or Ngai camphor* (*l-borneol*), $C_{10}H_{18}O$.

This variety of camphor, as has already been mentioned, is manufactured from the Blumea balsamifera D.C., which is called *ngai* by the Chinese. The crude Ngai camphor, *ngai-fên*, appears in dirty white crystalline grains and contains more or less of vegetable remains as impurities. The refined Ngai camphor, which is called *ngai-p'-ien*, is, however, perfectly colourless.

Ngai camphor is scarcely known in Europe, but in China it is largely used by the natives as medicine and for ritualistic purposes, and also in the preparation of the finer qualities of india ink.

Pure Ngai camphor is perfectly similar to Borneo camphor in all particulars excepting in its direction of rotation of the plane of polarisation. While Borneo camphor consists of d-borneol, that is, borneol which is optically dextrogyrate, Ngai camphor is the lævogyrate modification of borneol found in nature. Thus these two varieties of camphor differ only in optical properties, but as regards their composition, general properties and chemical behaviour they bear complete resemblance to each other.

That Ngai camphor is identical with l-borneol was first established in 1874 by both Plowman (*Pharm. Journ.*, III, 4, p. 710) and Flückiger (*ibid*, III, 4, p. 829). The fact has been verified recently[1] (*Bericht von Schimmel & Co.*, Leipzig, Apr. 1895, p. 74).

COMPARATIVE TRADE VALUE OF THE THREE PRINCIPAL CAMPHORS.

A few words may here be said about the comparative commercial importance of the three varieties of camphor described above in order to indicate clearly the position held in trade by the Ngai camphor, the manufacture of which on an industrial scale it has been proposed to take up in Burma. Of the three varieties Borneo camphor is the rarest and the most expensive. Next in point of price comes the Ngai camphor, while the 'common' or Chinese camphor is the commonest and the cheapest of the three varieties. Borneo or Barus camphor is known to be selling at more than a hundred times the price of the crude Laurus or common camphor of China, while Ngai camphor is about ten times the price of the latter.[2] Barus (Bhimsaini) camphor has always been regarded in India as possessing peculiar virtues, and it is said that a conscientious *Vaid* (Hindu physician) would not use any other variety of camphor in the preparation of his medicines than the Bhimsaini, for it is that variety which is recommended for medicinal purposes in his sacred and ancient works on medicine.

By the fact that Barus camphor is most highly prized in Eastern medicine, coupled with the fact that the article is obtained only in small quantities and with an immense amount of labour, might be accounted for the enormously high prices (about Rs. 80 a lb.) at which it sells.

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1 See Gildemeister and Hoffmann, *Volatile Oils*, Kremers' American Edition (1900), p. 669.

2 *Vide* Dicy. of Econ. Prod. of India, Vol. II, Camphor, pp. 86-87. Also Agricultural Ledger, 1896, No. 5, p. 3

Ngai camphor which is at present manufactured only in Hainan and Formoso and at Canton, so far as Eastern opinion regarding its excellence and peculiar virtues for medicine is concerned, is second only to Barus camphor.

It will thus be seen that in point of commercial value Ngai camphor holds an intermediate position between Barus and common camphors.

METHODS OF ASSAYING A CAMPHOR-YIELDING PLANT.

The estimation of volatile oil is the chief thing in the analysis of a camphor-yielding plant or any plant which contains volatile oils. Besides this, water determinations are also made in such plants or their parts, both in their fresh green state and when they have been dried in the shade. These water determinations serve in comparing the yields (per cent.) of volatile oils from the plants in their fresh and dry states and further in comparing the oil determinations in different samples calculated on the dry material.

Moisture Determination.

The moisture determination is made as usual. About 3—4 grams of the leaves in small fragments or of the stem or of other parts of the plant carefully cut up into thin slices are accurately weighed and dried at 100°C. till the weight is constant. A slight inaccuracy in this determination occurs on account of most of the volatile portions of the plant escaping at 100°C., and in consequence being calculated as moisture, but since the percentage of volatile oils is generally very small in the plants in question, the water determination may be regarded as (very approximately) correct for all practical purposes.

Volatile Oil Determination.

As the percentage of volatile oils in plants is generally low, it is rather difficult to determine exactly the percentage of the oil present. The estimation is generally made by two methods, which are described below.

(1) *By steam distillation.*—A weighed part of the plant, sufficiently and suitably comminuted, in which the amount of volatile oils is to be determined, is distilled by passing steam over it, and the distillate consisting of condensed steam and volatile oil is shaken with ether, which dissolves out the whole of the volatile oil present in the distillate. The etheral solution of the volatile oil thus obtained is then dried over calcium chloride, rapidly filtered and carefully distilled over. The residue is weighed as volatile oil. Obviously the results obtained by this method are only approximately correct.

(2) *By extraction.*—About 10—20 grams of the leaves broken into small fragments or of the stem or roots cut up into fine shavings are extracted with dry ether in a Soxhlet's Extractor for about six to ten hours, and the material allowed to be thoroughly exhausted of all material soluble in ether. From the extract thus obtained the ether is removed by distillation and the residue dried over the water bath and then in a desiccator to a constant weight. The weight of the extract is noted as No. 1.

The volatile oil contained in the extract obtained by the first operation is next separated by steam distillation. The operation takes about 15—20 minutes. The residue is thoroughly dried on the water bath and finally in an air bath till of constant weight. This weight is noted down as No. 2.

The total amount of volatile oil contained in the material taken is then calculated by the difference (No. 1 *minus* No. 2).

It is easy to see that the method just described gives more accurate results than the first method.

For practical purposes, forty to sixty pounds of the plant are distilled in a large copper still with a sufficient amount of water for 8—10 hours, and the oil separated from the distillate by means of a Florentine flask or otherwise. In this way, fairly large quantities of the oil may be obtained for investigation of its properties. This process has also been used for the quantitative determination of the essential oils in plants. But the two methods described above being much more convenient and speedy are recommended, when the object of the analysis is merely to get a fairly accurate idea as to the expected yield of volatile oil from the plant.

THE ASSAY OF THE BLUMEA OF BURMA.

The stearoptene or camphor exists in general[1] dissolved in the essential oil, which, it appears to be well established, permeates the entire plant which yields it from the roots to the flower. The amount of the solid stearoptene suspended or dissolved in the essential oil increases with the age of the tree, so that the older trees yield more camphor and less camphor oil, the exact contrary being the case in the distillation of the younger trees. The proportion of camphor oil in the essential oil also varies with the season, its yield being as a rule larger in hot than in cold seasons. But, whatever be the ratio of solid camphor and camphor oil in the essential oil, it is clear that the yield of the camphor from a tree depends on the amount of the essential oil which can be extracted from it. Thus, the chief thing in the assay of a camphor-yielding plant is the estimation of essential oil contained in it.

[1] In very old trees camphor (both Barus and common variety) is found crystallised in cavities and fissures of the heart wood.

The following series of determinations of the percentage of essential oil contained in the *Blumea balsamifera* of Burma were made with the object of ascertaining whether the yield of the essential oil from that shrubby composite was sufficiently large to encourage the distillation of this plant in Burma on an industrial scale. These analyses were made both in Burma with the fresh green plants and in Dehra Dun with the dry baled samples. The essential oil determinations were made according to method No. 2 described on page 277, above.

For the purpose of comparing the yields of the oil from different samples the percentage yield of the oil has also been calculated on the dry material.

Sample No. 1.—From a *Toungya* near Taungoo. Height of the plant, 8 feet; girth near the root, 4 inches. Analysed in the morning following the evening on which it was cut. The wood of the stem, when cut up, found yellowish and of a fine, close grain. Odour of cut up roots, strongly camphoraceous; of stem less so, and of bruised leaves mixed.

TABLE NO. I.

Sample.	Part of the plant.	Moisture.	Volatile oil.	Volatile oil on dry plant.
B. balsamifera D.C. (Taungoo), Fresh green.	Leaves	37·14	1·20	1·91
	Roots	51·45	0·97	1·99
	Stem	52·75	0·39	0·83

It will be seen that the roots and the leaves are nearly equally rich in volatile oil. The yield from stem, too, is fairly satisfactory. Since the roots cannot always be made available for distillation, further assay of these was omitted.

Sample No. 2.—Fresh green leaves, and dry withered leaves hanging on the plant, collected from Mawhan forests, Katha Division. Analysed at Mawhan about 5 hours after plucking. Dry leaves easily crumbled, with pure strong camphor-like odour; fresh leaves smelt like the Taungoo sample.

TABLE NO. II.

Sample.	Part of the plant.	Moisture.	Volatile oil.	Volatile oil on dry plant.
B. balsamifera D.C. (Mawhan).	Green leaves	60·96	0·64	1·64
	Withered dry leaves.	13·45	0·92	1·06

This analysis shows that the percentage of the oil in the dry withered leaves calculated on the sample with moisture is greater than in the fresh green leaves, but it will be seen that the same calculated on perfectly dry leaves is much less than in the case of the fresh leaves. The conclusion to be drawn from this is that the sun had injuriously affected the quantity of the oil in the withered leaves. This might also have been inferred from the fact of the essential oils being generally greatly volatile.

Sample No. 3.—This sample, consisting of leaves and branches packed in gunny bags, was thoroughly dried in the shade at Taungoo before its despatch to Dehra Dun. On opening the bags the leaves were found to be almost like the withered leaves in sample No. 2, but with this difference that the camphoraceous odour in them was fainter than in the latter. This sample was analysed six months after it was collected.

TABLE NO. III.

Sample.	Moisture.	Volatile oil.	Volatile oil on dry leaves.
Blumea balsamifera shade-dried leaves from Taungoo.	14·70	1·60	1·88

Sample No. 4.—This sample, consisting partly of fresh and partly shade-dried leaves, was from Mawhan forest. It was packed in wooden boxes instead of gunny bags, and was received and analysed at Dehra 35 days after it had been collected. The leaves were found to be in a mouldy condition, some sort of decomposition having set in in the constituents of the leaves during transit through want of aeration or some other cause. The leaves emitted an almost fetid smell, the odour of camphor being only very faint, covered as it was by the hay-like and herbaceous odour of dry leaves and the bad smell of the decomposition products of the rotten leaves.

TABLE NO. IV.

Sample.	Moisture.	Volatile oil.	Volatile oil on dry leaves.
Blumea balsamifera (decomposed and rotten during transit) from Mawhan forest.	20·90	1·09	1·38

Judging from the percentage yield of the shade-dried leaves and comparing it with the results obtained from fresh green leaves (*vide* Tables Nos. I and II), it will be seen that there is but little difference in the green and shade-dried plant, so far as the amount of essential oil in them is

concerned. But it should be noted here that the yield is considerably decreased by exposure of the leaves to the sun.

The difference in the percentages of the essential oil (calculated on dry material) from the Mawhan fresh and shade-dried samples is rather more marked than in the case of the Taungoo samples. The loss in the case of the former is of course accounted for by some of the oil having deteriorated by contact with the decomposition products of the rotten material in the leaves.

Samples Nos. 5 and 6.—*B. balsamifera* being merely a small shrubby composite, it can of course bear no comparison with the gigantic forest tree, *Cinnamonum camphora*, the wood of which yields the common Japan and Formosan camphor in such large quantities that the manufacturer does not care to utilise the branches and the leaves which recent investigation (Hooper, *Pharm. Journ.*, Jan. 11th, 1896, 56, p. 21) has shown to be fairly rich in camphor and camphor oil. But it was thought necessary, or at least greatly desirable, to assay for comparison the leaves and branches of *Cinnamonum camphora* for the essential oil contained in them. The yield of the oil from other parts of this tree need not have been compared with the yield from B. balsamifera for the reason already indicated, *viz.*, the amount of the oil from the wood of the former is always far more than can be obtained from the latter.

Accordingly, I secured, through the courtesy of Mr. Beadon Bryant, Chief Conservator of Forests, Burma, a fresh green branch of *C. camphora* growing in the compound of his office at Maymyo. The tree from which it was cut was a young one. It, together with the leaves, was analysed at Mandalay two days after it was cut at Maymyo. The other sample, taken from an old tree growing in the park of the Imperial Forest College at Dehra Dun, was assayed after it was thoroughly dried in the shade.

TABLE No. V.

Sample.	Part of the tree.	Moisture.	Volatile oil.	Volatile oil calculated on dry material.
C. camphora grown in Maymyo, No. 5, Fresh green.	Leaves . .	37·15	2·61	4·15
	Branch stem (girth 3″).	25·61	1·45	1·94
C. camphora grown in Dehra Dun College Park, No. 6, Shade dried.	Leaves . .	6·61	4·12	4·41
	Branch stem (girth 9″).	27·38	2·11	2·91

The results in this table confirm the impression gained from a comparative examination of the odours of the bruised leaves of *C. camphora* and of *B. balsamifera*, made by smelling both alternately, that the leaves of the former contained more camphoraceous (volatile) matter than those of the latter. It is thus evident that *B. balsamifera* can never be made a successful rival of *C. camphora* unless perhaps it were by means of artificial cultivation.

Attention may incidentally be drawn here to the important suggestion first made by Mr. Hooper (*loc. cit.*) that the leaves of *C. camphora* could profitably be utilised for the manufacture of common camphor in India and elsewhere.

Sample No. 7.—Blumea lacera D.C. (Burmese, *Kadu*).—There are other species of Blumea than B. balsamifera, the leaves of which when bruised emit a camphoraceous odour. My attention was drawn to one of these at Pynmana. The inside of the wood of this plant was found to be white and soft. Both the leaves and the stem when crushed exuded much liquid matter, and possessed a strong camphor-like odour. It was identified for me afterwards as *Blumea lacera* by Mr. W. W. Smith, Curator, Sibpur Herbarium, Calcutta. The following determinations were made at Pynmana in a mixture of the leaves and very fine stems of this species :—

TABLE NO. VI.

Sample.	Moisture.	Volatile oil.	Volatile oil calculated on dry material.
Blumea lacera (Pynmana)	67·20	0·67	2·04

The oil obtained from *Blumea lacera* has a specific gravity of 0·9144 at 26·7° (Dymock), which is nearly the same as that of the oil of Borneo camphor, sp. gr. at 15°C. 0·882—0·909 (Macewan). This would suggest that both oils contain a mixture of terpenes and their oxygenated derivatives nearly in the same proportions. Considering that the percentage of the essential oil from *B. lacera* calculated on the dry material is as much as, rather larger than, in *B. balsamifera*, it is obvious that the former variety of Blumea, too, merits our attention, as an abundant supply of it can be obtained in Burma.

Ngai camphor from samples Nos. 3 and 4.—It has not yet been possible to make an exact determination of the percentage of solid camphor in the oil obtained from the *B. balsamifera.* Small quantities of the oil from samples Nos. 3 and 4 were, however, collected in a beaker which was covered with a watch glass. On cooling the latter, snow-like crystals of the camphor were seen subliming on the bottom of the watch glass. The appearance of these crystals when seen under the microscope is shown in Plate VI.

The preceding determinations, as has been already stated, were made according to the method No. 2 described on page 277, above. In that method, since the volatile extractive matter is isolated from the plant by means of ether, the estimation of the volatile matter is therefore very accurate. It is, however, difficult to obtain in practice the yield of the volatile oil as determined by this method, for in that case the extraction is effected not by ether, but by means of water or steam distillation by which more or less of the volatile extractive matter is decomposed through the action of heat, water or other causes. Further, while ether can extract the whole of the volatile matter present in the plant, water may leave behind more or less of this volatile matter. To ascertain, therefore, the yield of the essential oil extractible by water, the following trials preliminary to experiments on distillation on a large scale were made by steam distilling the plant according to the method No. 1 described on page 276, above. Another object of these preliminary trials was at the same time to determine the conditions most favourable for the extraction of essential oil by means of water. These trials were made only with the shade-dried plant, it having been discovered from the results of the preceding analyses that drying in shade had practically no injurious effect on the quantity of the volatile oil.

Sample No. 3.—Shade-dried leaves from Taungoo : 100 grams of the leaves were first distilled by passing a rapid current of steam over it, and the distillate collected in a receiver, and the isolation of the oil from the distillate proceeded with as directed in the method No. 2. The receiver in which the distillate was collected was at the temperature of the room in this trial. The percentage yield of the essential oil was found to be 0·209.

It was observed during this trial that the quantity of camphor oil floating on the distillate became towards the end of the operation of distillation somewhat less than in the first stages of distillation. It was hought that the loss was occasioned by the receiver not having been kept cool.

The assay was, therefore, repeated with a gentle current of steam, and the receiver kept cool by cold water running over it. The percentage yield of the essential oil found in this case was 0·361.

It is thus evident that rapid distillation will have to be avoided and the distillate will have to be kept cool as far as possible during the extraction of volatile oil from *B. balsamifera.*

Sample No. 5.—Leaves from Mawhan received in a mouldy condition. The percentage yield was 0·265.

Sample No. 7.—Shade-dried leaves of *Cinnamonum camphora* from the Dehra Dun College Park. Assayed under the same conditions. The percentage yield was found to be 1·658.[1]

PREPARATIONS OF CRUDE CAMPHOR BY CHINESE PROCESS.

10 lbs. =4535·9 grams of the leaves of the Taungoo shade-dried leaves (Sample No. 3) were distilled for 6 hours in an apparatus similar to that adopted by the Chinese for distilling Blumea balsamifera (*vide* Plate No. V). The oil was not separated in this way, but the amount of the raw camphor scraped from the bottom of the condensing lid on which it sublimed during the process of distillation was found to be 23·753 grams. It was of course very crude and was found to contain moisture amounting to 40·31 per cent. Deducting moisture the percentage of dry camphor as extracted by the Chinese process comes to ·211 calculated on dry leaves. Taking 1·88 as the percentage of the volatile oil in the leaves as determined by extraction, the dry camphor forms 11·22 per cent. of the total oil (extractible by ether). If we take 0·423 as the percentage of the volatile oil as determined by steam distillation, the yield of the camphor from the oil (extractible by steam) amounts to 49·88 per cent.

The crude camphor as obtained above was of a dirty white colour. When freed from moisture its specific gravity was found to be 1·06 at 25°C. (sp. gr. at 15°C. for pure l-borneol = 1·02).

It melted at 175—176°C. (m.p. for pure l-borneol = 203—204°C.). Evidently the camphor in question was not a very pure product. Its odour, however, agreed with that of common camphor, while it partook at the same time of that of amber as pure Ngai camphor does.

It is to be noted that the percentage yield from the volatile oil of B. balsamifera of Ngai camphor as obtained above by the Chinese process

[1] *Conf.* Bericht von Schimmel & Co., Oct. 1892, p. 7, where a sample of the dry leaves of Cinnamonum camphora is reported to have yielded 1·8 per cent. of oil.

cannot be regarded as correct, for the process employed for determining it was indeed a very crude one.[1]

The percentage yields of the essential oil from the shade-dried samples of *B. balsamifera* and *C. camphora* as determined both by the methods Nos. 1 and 2 and calculated on the dry material are for convenience of comparison tabulated below :—

Sample.	Volatile oil by extraction.	Volatile oil by distillation.
Blumea balsamifera, shade-dried leaves from Taungoo, No. 3.	1·88	0·423
Blumea balsamifera (decomposed and rotten during transit), from Mawhan forests, No. 4.	1·38	0·335
C. camphora growing in Dehra Dun College Park, shade-dried leaves, No. 6.	4·41	1·775

General Conclusions.

The conclusions that have been drawn from the above analyses may now be briefly summarised as follows :—After the roots, which cannot be utilised for the extraction of camphor, the leaves are the richest part of *B. balsamifera* as regards the yield of essential oil; and though the Chinese employ only the last three joints of a branch, the assay of the stem has shown that it together with the leaves can be profitably distilled for the extraction of the oil and camphor. Exposure of the leaves to the sun is detrimental to the quantity of the essential oil, but after the leaves have been gathered from the plant, they may, if desired, be dried in the shade. For it is practically immaterial whether the leaves to be distilled be fresh or shade dried. It has been found that in rotten leaves a part of the oil becomes degenerated. It is therefore extremely desirable that when the leaves are to be transported to a distant place, they should be thoroughly dried in the shade before their despatch, as in that case they are less liable to rot. The Chinese system of letting the leaves and

[1] It may be of interest to compare this yield of the camphor from the volatile oil of *B. balsamifera* with the yield of camphor from a sample of *Cinnamonum camphora* fresh leaves, which was determined by a better process and was found 10—15 p.c. of the oil in the leaves (Hooper, *loc. cit.*).

branches get wilted before they are put into the still appears to be unnecessary, unless it were in the case of the leaves that have to be taken to a long distance.

The distillation of the plant by means of water or of steam should be slowly conducted, and the receiver in which the vapours are conducted from the still should be kept as cool as possible.

It would thus appear that the Chinese system of distilling the plant in the winter months is perfectly justified, though of course the distillation may be carried on in the hot season if due precautions are taken in keeping the receiver cool during the process.

A few words may here be said about the moot points connected with the extraction of Ngai camphor, which have been indicated in a previous chapter, while reviewing the accounts of the Chinese process of distillation. In the first place, it is to be remarked that though the Chinese are not stated to obtain any oil as a by-product from the plant, it is nevertheless possible to do so, as in the case of other camphor-yielding trees. Secondly, to obtain the maximum yield of camphor from the plant there seems no need of subjecting it to any preliminary treatment excepting that of reducing it to a state in which the steam or the water may have an opportunity of rupturing and entering the plant cells and may bring the volatile oil contained in them to boiling point. The processes of the formation of both the oil and of the camphor in it in the tissue of the plant have not yet been understood, and so far it appears, therefore, that it is not possible to control the development of these substances in the plant with the object of increasing their yield. Thirdly and lastly, other species of Blumea can be utilised as well as B. balsamifera for the manufacture of Ngai camphor.

As regards the ready sublimations or crystallisation of camphor in the oil by the addition of some substance to the latter or otherwise, the question is under investigation and will possibly be dealt with in a future note on the subject of the manufacture of Ngai camphor.

The above notes must be regarded as a preliminary and only very partial enquiry into the extraction of Ngai camphor from *B. balsamifera* of Burma. There is no doubt that the results of the assay of the plant as given above are decidedly encouraging. But in practice when the distillation of the plant is carried on on a large scale, the yield of the oil must become, as has already been stated, much smaller than the preliminary assay has shown. For there are numerous causes at work during the process of distillation by which more or less of the volatile oil originally present in the plant is very likely to be rendered wholly useless or

unavailable. Among these causes may be mentioned the heat, the water and the action of the products resulting from the decomposition of the plant material, and the changes brought about by these in the composition of the volatile oil consist, according to Gildemeister and Hoffmann (*loc. cit.*), of 'reduction, oxidation, polymerization, condensation, saponification of esters, etc.'

It is thus evident that in order to definitely ascertain whether it would be worth while to extract Ngai camphor from the Blumea of Burma as an industrial undertaking, further experiments require to be made on the quality and yield of the oil and of the camphor obtained by distilling the plant on a large scale with some approximation to the conditions which obtain in practice. For the purpose a large copper still has been specially devised and is under construction, and as soon as it arrives in Dehra, large quantities of the shade-dried plant will be subjected to steam distillation to make a practical estimation of the percentage yield of both camphor and the oil. Till then no reliable opinion can be formed as to the possibility of Blumea of Burma becoming an important commercial source of Ngai camphor. Further, in this way sufficiently large quantities of the oil of Ngai camphor will be made available to admit of an examination of the properties and chemical behaviour of the oil and of its portions obtained by fractionation, whereby it will be possible to determine the uses to which the oil and its fractions might profitably be devoted.

CALCUTTA : PRINTED BY SUPDT. GOVT. PRINTING, INDIA, 8, HASTINGS STREET.

Plate IV.

Blumea balsamifera. For full description see page 271.

BLUMEA BALSAMIFERA, D.C.

Plate V.

It represents the extremely simple Chinese apparatus for the extraction of camphor from Blumea balsamifera. On an iron cauldron is fixed a bamboo-woven cylinder, "leaped," straw rope bands at both ends. A smaller cauldron is placed at the top of this bamboo basket and is kept cool.

Height of the bamboo basket $17\frac{1}{2}''$.

THE CHINESE APPARATUS FOR DISTILLING NGAI CAMPHOR.

Plate VI.

Figs. 1 and 2 showing snow-like crystals of *Ngai* camphor freshly sublimed.

CRYSTALS OF SUBLIMED NGAI CAMPHOR.

VOL. I PART IV

THE

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CALCUTTA
SUPERINTENDENT GOVERNMENT PRINTING, INDIA
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Price Rs 1 and annas 4 or 2s.

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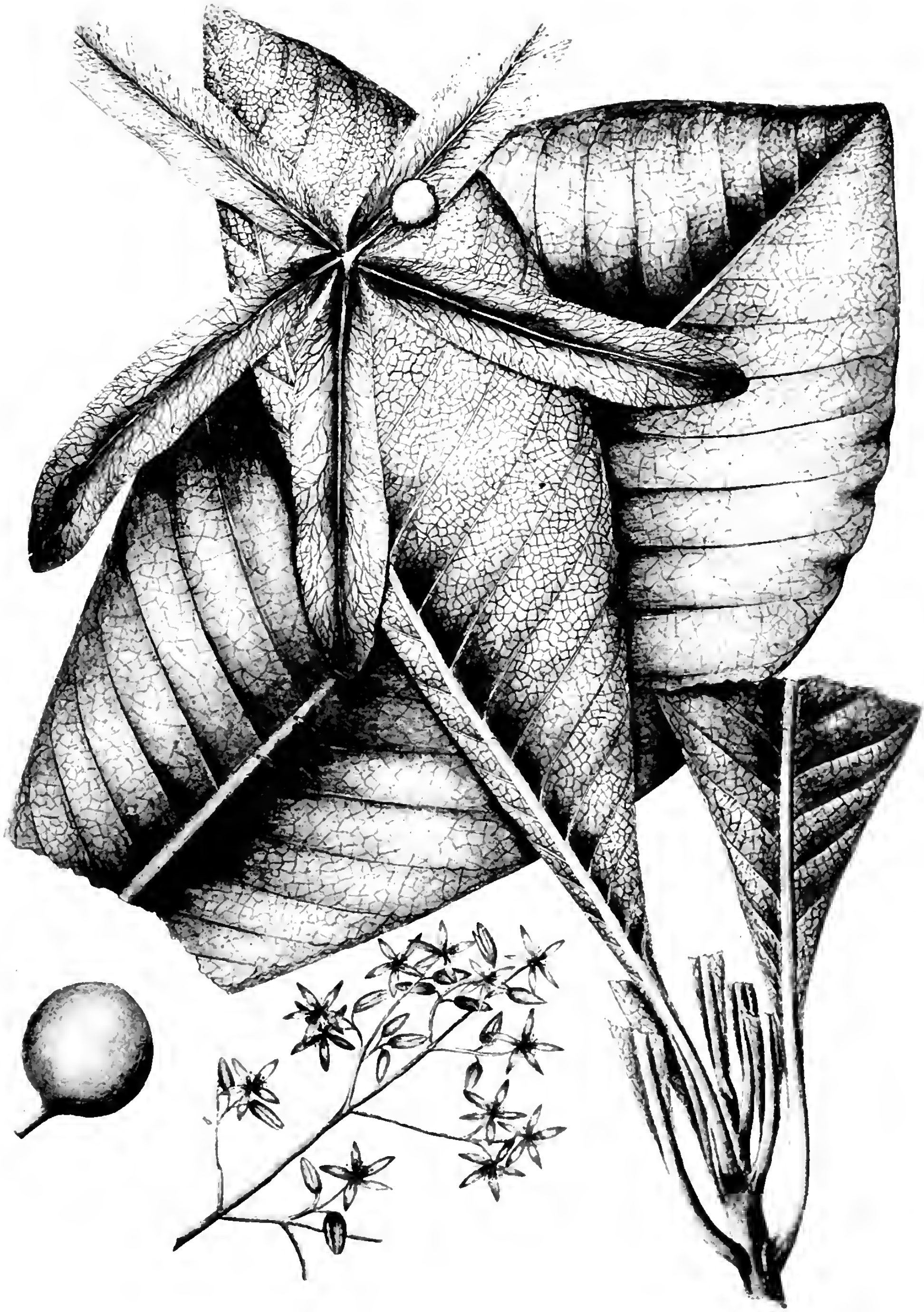

J.B.Singh, del.

Melanorrhoea Usitata.

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Vol. I] 1908 [Part IV

A Chemical Investigation of the Constituents of Burmese Varnish (Melanorrhœa Usitata Sap.)

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THE varnish used in the well-known Burmese lacquering art is derived from *Melanorrhœa Usitata* (Burmese, *thitsi*, a large deciduous tree occurring abundantly in Burma and Siam. The tree belongs to the order of Anacardiaceæ and is closely allied to the well-known lacquer tree of Japan, *Rhus vernicifera* (Japanese, *Urushi-noki*), which is a member of the same natural order. It is very abundant in the Eng (*Dipterocarpus tuberculatus*) forests of Pegu and Tenasserim. It does not attain the same size as the Eng, and when the trees are in foliage, it can be easily identified by its leaves, which resemble those of *Semicarpus Anacardium*, but are different in shape from those of the Eng or other species found along with it in the forest, and moreover are somewhat darker in colour. Besides the varnish, the timber yielded by the tree is very valuable and is used for making furniture, gun-stocks, tool-handles, etc.

The sap extracted from the bark of the tree constitutes the raw varnish. It is obtained by making two slanting slits through the bark with a peculiarly shaped iron chisel, thus slightly raising and detaching from the inner bark a triangular piece of the outer bark with its apex towards the bottom of the tree. The sap, which issues

from between the outer and inner barks, is collected by means of a hollow bamboo which is thrust into the bark just below the apex of the above-mentioned triangular piece of the outer bark. The flow of the sap is rather slow, and 10 days are allowed to pass before the bamboo is emptied. A similar cut is then made in the same triangular piece of bark a short distance above, and the sap collected for another 10 days after which it ceases to flow, necessitating fresh incisions in other places on the stem.[1] The crude varnish thus obtained may be purified by carefully straining it through strong cotton cloth.

The uses of the Burmese varnish are varied and manifold as those of the Japanese lacquer. It has been employed to varnish wood, stone, iron and leather, and to make paper and cloth waterproof. Mixed with saw-dust, cow-dung ashes, bone ashes or prepared rice husks, it is used for groundwork or as a cement or a moulding material. To attain the final degree of polish only the pure liquid obtained by pressing the natural varnish once or twice through strong cloth is used. Different colours may be imparted to the varnish by adding to it lamp black, indigo, orpiment, vermilion, gold and silver leaf, etc.

The Burmese varnish in its pure natural state is very similar in appearance to the pure Urushi or Japanese lacquer. The latter under the microscope appears as a brown emulsion consisting of minute globules of two kinds,—very numerous small globules of darker colour and more sparsely scattered large globules of lighter colour—mixed up with minute particles of some opaque brownish matter (Rein, *Industries of Japan*, p. 346: H. Yoshida, *Journal of the Chemical Society*, Vol. XLIII, 1883, p. 474). Perfectly agreeing with this description is the appearance of the Burmese varnish when examined under a powerful microscope (*vide* Plates).

Briefly described, the principle of the lacquering process is as follows:—First the imperfections in the article desired to be varnished are filled up with a putty made of inferior qualities of lacquer mixed with some suitable substance such as saw-dust, cow-dung ashes or rice paste. After this the varnish is repeatedly applied, and before each application care is taken that the previous coat has perfectly dried. The drying of all lacquer coats must

[1] For a detailed description of the process of extraction of the crude varnish reference may be made to Sir D. Brandis' Notes on the Burmese Varnish, etc. Indian Forester, Vol. I. No. 4, p. 362.

take place in damp unwarmed atmosphere, as genuine lacquer will set neither by the aid of heat nor by sun light nor in dry atmosphere. The Burmese lacquerer dries his wares in a dark subterranean cellar, while in Japan the necessary conditions are fufilled by choosing a chest, cupboard or chamber, the air of which is kept constantly moist by artificial means. After each application the freshly dried coat must be rubbed, smoothed and polished. The operation of polishing need not be very perfect, if the surface has been roughly polished before; but the polishing of the uppermost coat towards the final stage of the lacquering process is very important and should be done as thoroughly as possible. After the article under treatment has been coated with varnish and coloured to the desired extent, it is painted all over with the fine, finishing lacquer, which, as has been said above, is obtained by straining the varnish once or twice through strong cotton cloth.[1] The coat is allowed to dry, then rubbed down and finally polished. This application of the pure fine varnish is repeated, and the dried coat is rubbed down and polished as often as necessary till the requisite degree of polish has been obtained.[2]

It is to be noted that the principle of the lacquering process as practised in Japan is identical with that of the Burmese process as described above. (*Cf.* Sir George Watt, on Burmese Lacquer Ware, *Kew Bulletin*, 1905, No. 5, pp. 142-143; Prof. J. J. Rein, *loc. cit.*, p. 356, and p. 357 *et seq.*)

The remarkable similarity in appearance of the Japanese and Burmese varnishes, coupled with the fact that the methods of their employment in lacquer work in Japan and Burma are similar in many respects, led the author to suppose that the two lacquers might be identical in chemical composition. The present investigation was undertaken with a view to deciding whether or not this supposition is correct.

I am not aware that anything has so far been done to investigate the chemical composition of the Burmese varnish with the exception of some simple experiments by Sir David Brewster (*vide infra*, p. 5) by which he showed that the economic value

[1] In Japan the varnish is said to be trained through *Yoshina-goma*, also called *Urushi-Koshi*, *i.e.*, lacquer filter (J. J. Rein, *loc. cit.*, p. 356). Yoshino-gami is a fine variety of the soft, flexible and porous but very firm papers made in Japan from *Broussonetia Papyrifera*.

[2] George Watt, *Burmese Lacquer Ware and Burmese Varnish.*

of the varnish depended on the reduction, by the atmospheric air, of its organised structure to a state of complete homogeneous fluidity. Urushi, *i.e.*, Japanese lacquer and its constituents have, however, been completely investigated. The first important contribution to the chemistry of Urushi was that made by Mr. S. Ishimatsu of Tokyo in a paper communicated through Professor Roscoe to the Philosophical and Literary Society of Manchester (February 18th, 1879). He shewed that the constituents of Urushi are a resin, a gum, water, and a small quantity of diastatic matter insoluble in water and alcohol. These constituents were afterwards made the subject of a complete investigation by H. Yoshida (*loc. cit.*) and by the same author in association with O. Korschelt (*Transact. As. Soc. Japan*, xii, pp. 182-220). It was shown by these authors that the most important and predominant ingredient of Urushi is its resin which is extracted by pure alcohol. The name *Urushic acid* was given to this constituent. Its chemical composition was ascertained, and is represented by the formula $C_{14}H_{18}O_2$. It does not dissolve in water, but is soluble in pure alcohol, benzene, ether, carbon disulphide and some other organic solvents. It is a very stable body of pasty consistence, and unlike the original Urushi refuses to dry when exposed to moist air.

The gum was shown to be a complex mixture of the metallic salts of arabic acid, $C_{12}H_{22}O_{11}$. It exists in Urushi in the form of aqueous solution, and it was shown that it takes no part in the process of the drying up of lacquer, as its aqueous solution was found to produce absolutely no change in Urushic acid, even when a mixture of these (in the proportion in which they exist in the natural juice) was exposed to the conditions most favourable for the drying of the original Urushi. The aqueous solution of this gum, it was suggested, keeps the constituent particles of the lacquer in a state of intimate emulsion, and besides increases the adhering power of the lacquer. The third constituent was ascertained to consist mainly of a nitrogenous substance, and it was shown that it was the action of this diastatic matter on Urushic acid that caused the drying of the lacquer. An investigation instituted to test the activity of this constituent on Urushic acid under different conditions showed that moist oxygen or air at the temperature of 20°C. or thereabouts was a *conditio sine quâ non* for this nitrogenous constituent to display its fullest activity in causing the drying of the lacquer. It

was further shown that the activity of this diastatic or albuminous substance diminishes with increasing temperature till at 63°C., when the albuminoid coagulates in the form of a white precipitate, its drying power entirely disappears.

The hardening of the Urushi when exposed to a moist unwarmed atmosphere was shown to be due to a process of oxidation, which takes place by the aid of diastatic matter present in Urushi in the presence of oxygen and moisture (moist air), and which brings about the conversion of the pasty Urushic acid into a solid brown neutral substance according to the equation

$$2C_{14}H_{18}O_2 + O_2 = 2C_{14}H_{18}O_3.$$

This ultimate brown substance, to which the name oxy-urushic acid has been given, is an exceedingly stable body, which is absolutely unaffected by any of the solvents of Urushic acid, and it is to the presence of this oxy-urushic acid that the dry lacquer work owes its great power of resisting all disintegrating influences. Its chemical composition is represented by the formula $C_{14}H_{18}O_3$.

BURMESE VARNISH.

General Properties.

Pure Thitsi or the Burmese Varnish is a thick sticky greyish fluid of glutinous consistence, which at first darkens to a brown and finally assumes a jet black colour on exposure to the air. It has a peculiar sweetish odour and specifically is heavier than water but only slightly so. The specific gravity at 20°C. of a pure fresh sample derived from the M. Usitata of the Mawhan Forest was found to be 1·0016 (sp. gr. at 23°C. of *Pure* Japanese lacquer = 1·0020).

So far as I know, Sir David Brewster[1] is the only investigator who has ever examined the Burmese Varnish from a scientific point of view. Brewster experimented with the varnishes of Sylhet and Burma, and his experiments which were very simple were conducted as follows:—A thin transparent film of the varnish was obtained by pressing a small quantity of it between two glass plates. This film then examined under a powerful microscope showed the fluid to be an organised and not a homogeneous structure, as it was seen to consist of "immense congeries of small parts which exhibited the finest example of mottled or striated colours, (and which) dispersed

[1] Edinburgh Journal of Science (Vol. VIII, 1828) quoted by Sir George Watt

the sun's rays in all directions like the thin film of unmelted tallow or like organised fluids such as blood and milk." The film between the plates, on the edges of which a portion of the varnish was squeezed, was then let stand exposed to the action of the air for two days, after which period it was observed that the portion between the plate glasses on which the air had had no action was of the same structure as before, while the outlying portion which had been in contact with the air, having lost its organised structure through the action of the air, had become "perfectly homogeneous and showed the sun of a beautiful red colour."

EXPERIMENTAL.

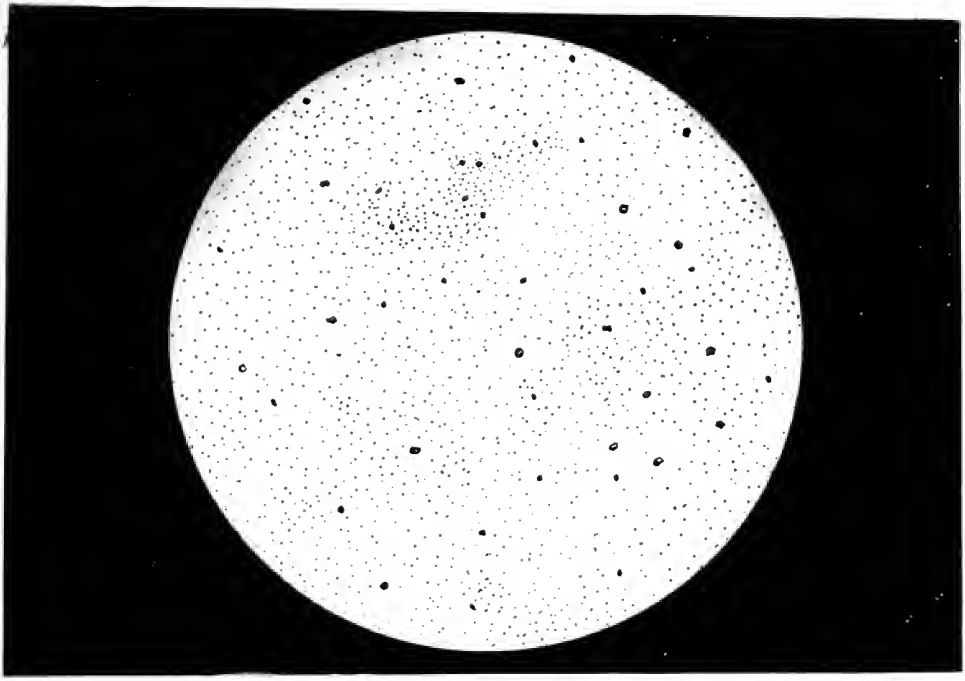
Microscopical Examination.

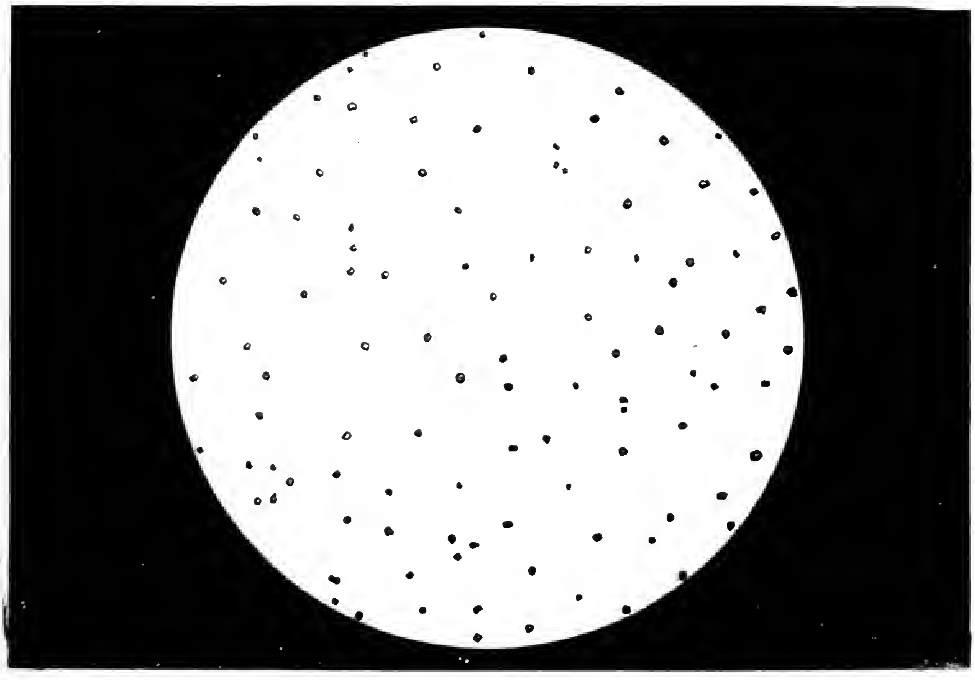
A careful microscopical examination of the "immense congeries" of small particles, which Sir D. Brewster found the Burmese Varnish to consist of, reveals two distinct kinds of these particles,—some very numerous small globules, dark brown in colour, and some light coloured large globules which are scattered more sparsely than the former (*vide* Plates). On treating the varnish with alcohol the former densely scattered kind of globules disappear (*vide* Plate 8).

It will thus be observed that the Burmese Varnish exhibits under the microscope exactly the same structure as the Japanese lacquer (see above, p. 288).

Chemical Examination.

When the residue after separating the part soluble in alcohol is boiled with water, it is found that the large light coloured globules which are insoluble in alcohol are dissolved, thus showing that the varnish under investigation is of a gummy resinous character like the Urushi of Japan. The method of separating these and other constituents of the Burmese Varnish which I followed was a slight modification of the method adopted by Ishimatsu and, following him, by H. Yoshida (*loc. cit.*) in analysing the Japanese article. A quantity of the varnish freed from bark pieces was treated with hot alcohol to separate the resinous constituent, and the extract dried at 105°C. In this way a brownish paste-like extract (A) was obtained. The residue was then shaken with dry ether, the ethereal extract distilled, dried and again treated wtih warm alcohol, which





J.B.Singh, del.

Pure Thitsi.

left behind a small quantity of some fatty or oily matter (this was not examined), and extracted the last traces of the resinous material which were added to (A). The residue from ether was next dissolved with a small amount of water, with which it was reduced to a slimy liquid state. The solution thus obtained was considerably diluted with water and boiled for some time, when a brownish precipitate separated out (thus indicating the probable presence of some albuminous matter). The precipitate was filtered off, and filtrate which contained the gummy constituents (B) was dried over the water bath till its weight was constant. The final residue (C), which was insoluble both in alcohol and in boiling water, was dried at 100°C. It was an opaque mass of a dark brownish colour like the insoluble constituent of the Japanese lacquer. It was found to contain nitrogen, and since the solution of the residue, which contained along with it the gummy matter and in which it was present presumably in its original soluble form, was precipitated by the action of heat, it was eventually inferred that it consisted of some albuminous substance.

Examination of the Alcoholic Extract (A).

The alcoholic extract dried at 105°C. was found to be a paste-like mass of a dark brown colour. It dissolved readily in benzole, ether, chloroform and carbon bisulphide, but was insoluble in water. Unlike the original thitsi, it refused to dry up when exposed to the action of moist air (see drying experiments below, pp. 304 & 305). Its specific gravity (20°C.) was found to be 0·9863. Its alcoholic solution gave the following reactions:—

Silver nitrate produced a dark precipitate, which on boiling deposited a shining mirror of silver on the sides of the tube.

With platinum chloride a gelatinous black precipitate was obtained, which on standing collected down to a pasty mass at the bottom of the tube.

On adding copper nitrate, a black colouration was produced in the alcoholic solution from which the copper salt separated in a finely divided condition on the addition of a large quantity of water.

The alcoholic extract was slowly dried at 105-110°C., to a constant weight, and analysed with the following results:—

0·1616 gram of the substance gave 0·4556 gram CO_2 and

0·1245 gram H_2O. C = 76·89; H = 8·56 per cent.[1]
Urushic acid, $C_{14}H_{18}O_2$, requires C = 77·06; H = 8·25 per cent.

With lead acetate solution a greyish flaky precipitate was produced, and this, according to Yoshida, is a very characteristic reaction of lead urushate. A determination of lead in this lead precipitate was made with the following result. The salt before analysis was thoroughly purified as in Yoshida's experiment, that is, it was first washed with alcohol and then with boiling water, carefully dried over a water bath, and finally over sulphuric acid in a desiccator till its weight was constant.

0·1966 gram gave 0·0684 gram PbO.
Pb = 32·27 per cent.

Lead Urushate, $(C_{14}H_{17}O_2)_2Pb$, requires Pb = 32·29 per cent. The lead salt was also burnt for carbon and hydrogen, but from the conditions under which the cumbustion was conducted it was believed that the determination of hydrogen was valueless.

0·1550 gram gave 0·2964 CO_2.
C = 52·16 per cent.

Calculated from $(C_{14}H_{17}O_2)_2Pb$, C = 52·42 per cent. This lead salt when heated to 100°C. darkened in colour to a brownish mass, emitting at the same time a peculiar odour. It melted at 113-115°C. On raising the temperature to 120°C., it was found to ignite and burn with a smoky flame. These observations agree very well with those of H. Yoshida made with the lead salt of Urushic acid.

The experimental evidence recorded above and the properties of the alcoholic extract under investigation leave no room for doubt that it is identical with the alcoholic extract of Urushi, which H. Yoshida has termed Urushic acid (sp. gr. at 23°C. = 0·9851).

In order to show clearly that the two are identical the following tabular statement of their properties and chief reactions may usefully be given here:—

[1] On calculating the formula from the percentage of Hydrogen found, it would be $C_{14}H_{19}O_2$ instead of $C_{14}H_{18}O_2$. But from the conditions under which the combustion was conducted I have reasons to believe that the combustion was a little too high in hydrogen.

This and other combustions in the present investigation were carried out in the Chemical Laboratory of the Thomason College, Roorkee, for allowing the use of which my best thanks are due to Major E. H. de V. Atkinson, R.E., Principal of that institution.

Substance.	Formula from combustion.	Specific gravity.	Reactions of an alcoholic solution with				Action of heat on Lead Salt.	Approximate melting point of Lead Salt.	Composition of the Lead Salt.
			Lead Acetate.	Silver Nitrate.	Platinum Chloride.	Copper Nitrate.			
Alcoholic Extract of Thitsi.	$C_{14}H_{18}O_2$	0·9863 (20°C.)	Greyish flaky precipitate.	A fine dark precipitate reduced to silver on boiling, showing a mirror of silver.	Solution gelatinised, gelatinous material on long standing cohering down to a pasty mass at the bottom of the vessel.	Solution blackened. Dilution with water caused separation of a finely divided copper salt.	Heated to 100°C., darkened and emitted a peculiar odour. At 120°C. ignited and burned with a smoky flame.	113-115° C. (but the melted mass had a dark brown colour).	Pb=32·27 per cent.
Urushic acid	$C_{14}H_{18}O_2$	0·9851 (23° C.)	Do.	Do.	Do.	Do.	Do.	110-115° C. (the melted mass of a dark-brownish colour).	Pb=32·29 per cent.

On treatment of the dry alcoholic extract with strong nitric acid, it was observed that it swelled up to a very bulky sponge-like mass of a yellowish colour. On long continued heating of the extract with strong hydrochloric acid, it became porous and swelled up though not to the same extent as when treated with nitric acid. Besides, the swelled up mass in this case finally assumed the appearance of caoutchouc. Urushic acid extracted from Urushi behaves exactly in a like manner. H. Yoshida has shown that nitric acid gives nitro-substitution products, while the action of hydrochloric acid produces a polymeric variety of Urushic acid.

On thoroughly mixing iron rust with Urushic acid, the latter was found to assume a very dull and browner appearance. This was due to the formation of a quantity of the Urushate of iron, as suggested by Yoshida. From this reaction it will be easily inferred that thitsi when brought in contact with iron, is liable to be contaminated with iron impurities especially in the presence of moist air. It should be noted that if these impurities are present in thitsi, they would interfere with the proper development of the required depth or shade of colour during preparation of the variously coloured and gilded varnishes, because of the very brown and dull appearance which they impart to thitsi.

Examination of the Aqueous Extract (B).

The gummy constituent, which was insoluble in alcohol and ether, was a light-coloured friable substance devoid of any taste, flavour or odour, and in appearance strongly resembled the ordinary gum arabic. In structure it was neither crystalline nor organised but was quite amorphous. It dissolved entirely in cold water, forming a glutinous frothy solution. With a small quantity of water, it gave a strongly adhesive mucilage.

In its composition and chemical reactions it hardly differed from gum arabic. Its solution, after treatment with nitric acid, gave with calcium chloride a white precipitate of calcium oxalate.[1] A solution of mercuric chloride, to which some solution of this gum

[1] When a gum, whether Arabinic, Cerasinic or Bassorinic, is oxidised with nitric acid, one of the products of oxidation is oxalic acid. Cerasinic and Bassorinic gums are insoluble in cold water, and with hot water assume only a gelatinous appearance. Arabinic gums, however, are almost completely soluble in water.

The formation of oxalic acid by oxidising the substance proves the latter to be a gum. Its complete solubility in water distinguishes it as belonging to the Arabinic class.

was added, refused to be precipitated by sulphuretted hydrogen. The solution of the gum was precipitated on the addition of ammoniacal lead acetate solution. The gum, after its "inversion" had been effected by heating it for some time with dilute hydrochloric acid (1 in 10), was found to reduce Fehling's solution, which when boiled deposited cuprous oxide (at first pale yellow and afterwards red). The substance before "inversion" had no such reducing action.

The dry material was redissolved, filtered, the filtrate was carefully dried over the water bath to a constant weight, and the purified *anhydrous* gum so obtained was incinerated with the following result:—

0·1305 gram gave 0·0074 ash = 5·7 per cent.

In Yoshida's analysis of the gum from Japanese lacquer (which he proved to be identical in all essential characteristics with gum arabic), 0·5267 gram of the gum gave 0·0267 gram ash = 5·1 per cent. Gum arabic (as well as other natural gums) contain 12-17 per cent. of water, and afford on incineration 2-4 per cent. of ash. Making allowance for the complete absence of water in the specimen of gum under investigation, it will be seen that its composition closely agrees with that of gum arabic. The ash was further tested for the presence of calcium, magnesium and postassium with affirmative results.

From the properties and reactions of the gum in question there can be no doubt that like the gum of Urushi, it, too, is identical in all essential characteristic with gum arabic.

In order to ascertain the part played by this gum in the drying of thitsi, a drying experiment was made as in Yoshida's investigation of the Japanese lacquer, that is, a quantity of this gum and water was thoroughly incorporated with the isolated alcoholic extract (now proved to be Urushic acid), the proportions of the three substances being roughly the same as found in the specimens of thitsi examined by the author (*vide infra*, p. 300). A glass plate was coated with this mixture and left to stand 48 hours exposed to the action of moist air the temperature of which ranged between 22 and 25°C. (see below drying experiment No. 5, p. 303). It was observed that the mixture did not dry and remained of the same consistency as before, thus showing that the gum, though useful in

increasing the adhering power of the varnish, took yet absolutely no direct part in the drying process.

Examination of the Nitrogenous Residue (C).

The albuminous residue (C), which was found to dissolve in cold water when it was not separated from gum, but which was precipitated from its solution on boiling, was an opaque mass of a brownish colour. A drying experiment similar to one performed with the gum, water and the Urushic acid was made with this substance also but with a negative result as in the case of the gum. But when the experiment was made with the residue which contained both this substance and the gum, it was found that the mixture of the residue, water and the Urushic acid dried almost in the same time as the original thitsi itself. Again when the same mixture was boiled before leaving it to dry, it was observed that its drying capacity was altogether lost. It was then naturally inferred from these experiments that as in the case of Japanese lacquer it was the action of the albuminous constituent as *originally present in the natural varnish*, on which depended the drying capacity of the latter, and that by coagulation the albumen lost its property of bringing about the drying of the varnish. The minimum temperature at which this constituent was found to coagulate is between 60-65°C. (See table of drying experiments below, p. 304). The coagulating point of the corresponding constituent of Urushi is 63°C.

Analysis of the completely dried substance furnished the following results:—

0·1055 gram gave 0·2211 CO_2 and 0·1044 H_2O and 0·0023 ash.
$C = 57{\cdot}15$; $H = 10{\cdot}99$; ash $= 2{\cdot}81$.

A determination of nitrogen by the Absolute or Dumas' Method was made with this result—

0·2120 gram gave 9·6 cc. moist nitrogen at 30°C. and 732 mm. $N = 4{\cdot}73$ per cent.

Thus the percentage composition of the substance was as follows:—

Carbon	57·15
Hydrogen	10·99
Ash	2·81
Nitrogen	4·74
Oxygen (by difference)	24·31
	100·00

The ash was found to contain traces of Sulphur and Phosphorus.

Nitrogen (by Soda-lime) as determined by Yoshida in the albuminous or diastatic constituent of the Japanese lacquer is 4·01 per cent. Nevertheless the composition of the diastatic matter under present investigation does not well agree with that of the corresponding constituent of the Japanese lacquer, which is quoted below for the purpose of comparison. This fact is, however, accounted for by the differences of origin, soil and climatic conditions.

Carbon	63·44	
Hydrogen	7·41	
Nitrogen	4·01	In the ash small quantities of sulphur and phosphorus were detected.
Oxygen	22·94	
Ash	1·20	
	100·00	H. YOSHIDA.

It is to be noted, however, that both these substances exist in the original juice as dissolved albuminates, which by the action of heat coagulate into insoluble albumen, and that both agree in containing a smaller amount[1] of nitrogen than other albuminous substances and in possessing that important diastatic action on Urushic acid to which the natural varnishes owe their drying power.

As regards the nature of the diastatic action on Urushic acid, it has been suggested that the disastase acts as a sort of ferment in the presence of moist air, oxidising the Urushic acid into what has been termed oxy-urushic acid, $C_{14}H_{18}O_3$ (see above p. 291). This oxidation product of Urushic acid was prepared in the form of a rich brown powder by oxidising the pure anhydrous alcoholic extract of thitsi with chromic acid mixture. It was found that it was refractory to all the usual solvents both inorganic and organic, even when it was boiled with them. It is thus evident that as in the case of the hardened Japanese lacquer the resistance of the dried thitsi paint to all those agencies, which are capable of disorganising the artificial varnishes, is due to the presence of this insoluble oxidation product of Urushic acid.

[1] This is Yoshida's observation and is based on the supposition that the nitrogenous residue is a pure albuminoid, but the diastatic constituents in question are very probably complex mixtures of an albuminoid with other undetermined substances, so that it may be that the albuminoid present, which it was found impracticable to isolate, is as rich in nitrogen as other albuminoids.

Quantitative Analysis of Thitsi.

The quantitative composition of 2 specimens of thitsi was determined according to the method of separating the constituents, which has been previously described. The moisture was calculated by difference, as its determination could not be made by the usual method of drying the substance at 100°C. in an air bath, owing to the above-mentioned action by which the Urushic acid takes up oxygen in the presence of moist air, the temperature of which is below the coagulation point of diastatic matter. The results of the analyses are as follows:—

	Sample No. 1.	Sample No. 2.
Alcoholic extract (Urushic acid) .	86·24	83·24
Gummy matter	3·08	3·52
Oily matter	*Nil*	0·53
Residue or diastatic matter . .	1·71	2·14
Moisture and other volatile matter (by difference).	8·97	10·57
	100·00	100·00

Sample No. 1 was fresh pure juice extracted from the trees of Mawhan Forest under the supervision of the Forest Ranger of Kadu (Upper Burma).

Sample No. 2 was a good specimen of thitsi bought from the Mawhan bazar.

Analyses of two purified samples of the Japanese lacquer may be given here for convenience of comparison:—

	Yoshino Urushi.	Hachioji Urushi.
Urushic acid	85·15	80·00
Gum	3·15	4·69
Oil	?	?
Residue (diastatic matter) . .	2·28	3·31
Water and volatile matter	9·42	12·00
	100·00	100·00

(Korschelt and Yoshida.)

It will be evident from these analyses that the composition of the Burmese varnish does not vary to any great extent from that of the pure Japanese lacquer, and should consequently possess about equal drying power with the latter. The slow drying power of the commercial Burmese varnish, as compared with the Japanese article, must, therefore, be attributed to the presence of extraneous

matters such as sesame oil, with which the pure juice is known to be commonly adulterated. This view is supported by the result of a drying experiment performed with a mixture of the pure thitsi with sesame oil (see below p. 305). The author believes that the presence of oily substances in natural varnishes paralyses to a more or less extent the catalytic action of the diastatic constituent in helping forward the drying process. The Japanese adulterate their varnish with linseed oil, which, if excess is avoided, does not, according to Yoshida, greatly impair the drying power of Urushi. For making lacquer of different colours, therefore, linseed oil (about 15 per cent.) would form a better substitute for sesame oil. Turpentine would still be better, but it imparts to the varnish a very brown colour.

The Japanese varnish contains a small proportion of an undetermined volatile substance of a poisonous character, which causes a very violent and painful itching to the parts of the body exposed to it. It is eliminated from the lacquer by stirring the latter in open shallow vessels. In the course of the present investigation I have not, however, found any such material in the two specimens of Burmese varnish examined, but it has been affirmed that the Burmese wood-cutters object to fell the *Melanorrhœa Usitata* trees, being afraid of some poisonous juice contained in the wood which produces a very disagreeable irritation and burning in the parts of the body exposed to it.

Thickening and Thinning of Thitsi.

Professor J. J. Rein (*loc. cit.* pp. 347-348) mentions that when purified urushi is closely mixed up with water, it loses its fluidity, thickening to a jelly-like mass which dries very quickly. Further, the thickened urushi may be reduced to its liquid state by the application of a slow heat or, if heat is to be avoided, by thoroughly mixing with it finely pulverized camphor or camphor oil. Precisely similar effects were produced when both liquid and thickened specimens of the Burmese varnish were treated as just described. No explanation of these peculiar effects has yet been given, but the suggestion may be offered that on the addition of water the large sparsely scattered globules of gum, which move about freely in the thin varnish, aggregate into larger masses (partial dissolution of

the globules taking place first through pestling or stirring the substance), and finally these aggregations of gum particles cohere into semi-solid adhesive masses, which act as a sort of binding material between the already densely-scattered resinous and other globules, thus thickening the whole mixture. On the other hand, when the thickened varnish is gently heated or is ground down with camphor, the solid adhesive masses of the gum melt or break up, giving off water which they had absorbed and thus gradually reducing to their original state. In this way, the gum particles themselves and the resinous and other globules are left free to move about, and the thickened varnish is brought once more to its original liquid condition.

Essential Conditions for the Drying Process.

In order to determine the essential conditions for the drying of the varnish, drying experiments were made with the original juice and various mixtures of its several constituents under different conditions. These experiments some of which have already been mentioned under examination of the constituents are summarised in the following table:—(For the purpose of shortening the period of drying only a very thin layer of the experimental material coated on a glass plate was exposed to the action of the air.)

Table of Drying Experiments.

No.	Experimental substance.	Conditions.	Time of drying.		Inference and Remarks.
			Left to dry at	Dried or not dried at	
1	Original Thitsi .	Kept under a bell jar along with a dish full of water. Atmospheric temperature 25° C.	10 A.M. .	Dried 8 A.M. next morning (after 22 hours).	Show that keeping the atmosphere of the drying chamber in as moist a condition as possible hastens the drying process.
2	Do. . .	Put in a wooden chest with pieces of wet cloth, hanging in the inside and also pinned on to the sides of the chest. The cloth pieces were soaked anew from time to time with cold water so that drops of water were made to fall constantly through the air of the chest; temperature 22-25°C.	Do. .	Dried 3-30 P.M. (after $5\frac{1}{2}$ hours).	
3	Do. . .	Exposed to dry air at 25° C. (in a desiccator over sulphuric acid).	Do. .	Not dried even after 2 days.	Shows that the presence of moisture in the air of the drying chamber is absolutely necessary for the hardening of the varnish.
4	Urushic acid alone with water.	Conditions same as in No. 2 .	Do. .	Not dried . .	Urushic acid alone, though the main constituent, cannot dry by itself,
5	A mixture of Urushic acid, gum and water.	Ditto	Do .	Do	Gum takes no direct part in the drying process, though it may indirectly help forward the hardening of the varnish paint.

Table of Drying Experiments—contd.

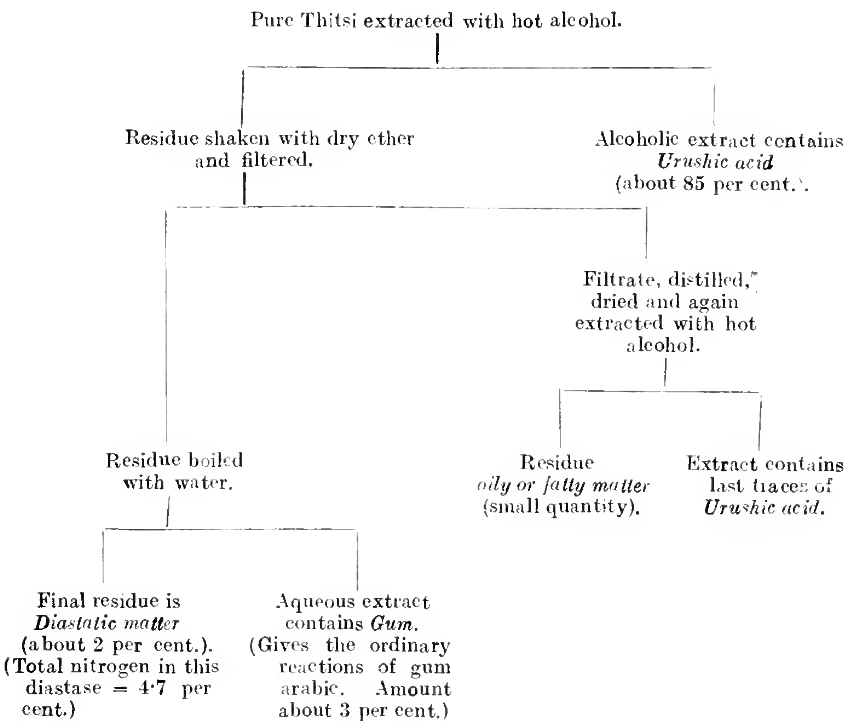
No.	Experimental substance.	Conditions.	Time of drying. Left to dry at	Time of drying. Dried or not dried at	Inferences and Remarks.
6	A mixture of Urushic acid, water and isolated (gum-free) diastatic matter.	Conditions same as in No. 2	10 A.M.	Not dried	
7	A mixture of Urushic acid with the unheated cold water extract of the original Thitsi (or with water and the residue which contained both gum and the diastase).	Ditto	Do.	Dried at about 5 P.M. (after 7 hours).	Show that it is the action of the diastatic constituent in Urushic acid which causes the hardening of the varnish, but the diastase to display this activity must be in its original soluble form as it is present in the natural varnish, as coagulation paralyses its action on Urushic acid.
8	The same boiled and allowed to cool before experiment.	Ditto	Do.	Not dried even after two days.	
9	Original Thitsi heated to 50°C. over water bath and then allowed to cool before experiment.	Ditto	Do.	Nearly dried at 4 P.M.	Show that the diastatic matter begins to lose its activity between 50 and 60°C. (White insoluble fibres of albumen begin to separate from the solution of the latter when heated to 54°C.)
10	The same heated to 60°C. and cooled before experiment.	Ditto	Do.	Not dried at 4 P.M. (not dried even after 24 hours).	
11	The same heated to 65° C. and cooled.	Ditto	Do.	Ditto	Diastatic matter entirely loses its activity between 60 and 65° C.
12	A mixture of Thitsi with sesamum oil.	Ditto	Do.	Not dried at 4 P.M., but nearly dried at 10 A.M. next day, after 24 hours.	Shows that sesamum oil (Burmese Shansi) greatly impairs the drying power of the varnish.

From the inferences drawn from these experiments it will be noted that the conditions which are essential for the drying of the Burmese varnish are identical with those which must obtain in the case of Urushi or the Japanese lacquer. It is to be further noted that the admixture of thitsi with sesamum oil as practised in certain stages of the Burmese lacquering art is not justified.

Attempts were made to discover some substance which, mixed with the varnish, would make it more quick-drying, but these have so far proved unsuccessful.

SUMMARY AND GENERAL CONCLUSIONS.

Separation of Constituents.



The present investigation has proved with the aid of the method outlined above that the most important and main constituent of the

Burmese natural varnish is urushic acid, which amounts to about 85 per cent. in the pure unadulterated specimens; and that this and other chief constituents of the varnish are identical in all essential characteristics with those of the Japanese lacquer; and finally that the principle involved in and the conditions essential for the hardening of the varnish paint are identical in the processes of lacquering with the Burmese and Japanese varnishes.

With a view to improving the lacquer industry of Burma the author makes the following recommendations:—

1. The iron chisels used for the extraction of the varnish should be perfectly clean and free from rust, as rust spoils the varnish by its action on Urushic acid.

2. In extracting the varnish care should be taken that it does not become contaminated with dust and other impurities, as the presence of the latter tends to prevent the uniform setting of the varnish during the hardening process, and besides gives to the final dried paint a dull appearance.

3. The juice extracted from the lower parts of the Japanese lacquer tree is known to be superior to that obtained from the upper part. The Japanese on this account collect the juice from the lower parts separately, and use it only for the final coatings of the lacquer ware. The same practice is recommended to be followed in collecting the Burmese varnish.

When it is desired to fell a tree, its branches can also be utilised for extracting a poor quality of the juice according to the method followed in Japan, *viz.*, the branches are bound together and put in hot water with about $\frac{1}{3}$ of their lengths out of the water. Incisions are then made in different places in the outlying parts of the branches, and the juice, which flows out by the aid of the heated water, is collected. The parts of the branches previously in water are finally treated similarly by turning the faggots and putting their exhausted parts in the heated water. The inferior juice thus obtained, mixed with bone ashes or other suitable material will be more advantageously utilized for ground work than the supposed inferior qualities of thitsi which are at present employed for the purpose.

4. The juice before storing should be thoroughly and continuously stirred for some hours in open shallow vessels with a flat paddle, as is done by the Japanese lacquerer. By this treatment

any volatile matter of a poisonous character, which may be present in the varnish, evaporates, and besides the particles of the varnish are brought to a more perfect state of uniform distribution than they would have without this treatment. It is extremely important, in the author's opinion, for the complete homogeneity of the final dried paint that the constituent particles of the varnish should be in a state of uniform distribution before application.

5. Iron[1] vessels should be scrupulously avoided in making lacquer of various colours as the rust from the iron vessels by combination with Urushic acid makes the colour of the varnish a dull brown.

6. In the underground cellar, where the lacquered ware is put to dry, arrangement should be made to keep hanging wet pieces of cloth, which should be soaked anew from time to time with cold water. Further the sides of the cellar should also be kept constantly wet in order to constantly maintain the necessary amount of moisture in its atmosphere.

If the air of the drying cellar is always kept damp in this manner to a sufficient degree, and if the varnish before storing or application has been stirred as described previously, it is hoped that the varnish will harden sooner than it would without observing these directions.

7. Finally, the importance of avoiding the use of sesamum oil as an adulterant may once more be emphasized here. Should the use of some oil be a necessity in certain stages of lacquering, linseed oil is recommended to be used instead of sesame oil.

The art of lacquering has been carried to a much higher state of perfection in Japan than in Burma. While the Japanese lacquerer, on the whole, has considerably improved this industrial art inherited from his ancestors, the people of Burma have shown comparatively little progress. Thus, in spite, of the great artistic ability of the Burmans, their lacquered articles cannot claim to equal, far less excel, the Japanese ware in the beauty and fineness of the paints and the richness and elegance of the decorations. This state of affairs, when the lacquers employed both in Burma and Japan are identical in all essential characteristics, is to be explained by the conservative spirit of the Burmese people who, it

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[1] Ferrous sulphate or acetate (from 0·5 to 2 per cent.) is used by the Japanese in preparing their black lacquer. But even this prepared black lacquer is not to be kept in iron vessels to avoid the increase of the iron contents.

appears, show absolutely no freedom in the choice of artistic ornamentation and in improving, as scientific investigation suggests, those rule-of-thumb methods which they have inherited from their ancestors.

There is no doubt that certain varieties of lacquer work, *e.g.*, gold ornamentation in relief, are the specialities of the Japanese, and in the making of these perhaps no people can successfully compete with them on account of the inimitable skill and true faithfulness to nature displayed in their production. But there seems no reason why the lacquering industry in Burma with a natural varnish as fine as that of Japan should not be developed in other directions to the same extent as it has in Japan.

For the purpose it is only required to introduce improved methods of preparing the various coloured and gilded varieties of the paint. The composition of the varieties, the number of the coatings to be applied, the final exact degree of polish, and the details of artistic ornamentation are all nice points, too difficult to be taught by description. From the taste for art which the Burmese possess, it is, however, hoped that they can learn all these with a few trials performed with a sufficient amount of skill, care and patience. Or if a regular lacquer industry were started in Burma or India by some enterprising firm, the services of a skilled Japanese lacquerer could be secured for the purpose.

In conclusion, the attention of the Forest Department may be drawn to the ruinous exploitation, as practised by the Burmese at present, of the trees, on the sap of which the lacquer industry depends. It is recommended that early steps should be taken to control the extraction of the sap, and proper attention be given to the systematic reproduction of *Melanorrhœa Usitata,* which yields not only a sap of such great economic value, but the timber of which, as mentioned in the beginning of this paper, is very valuable. It is thus hoped that the products of this species will form an important item of revenue to the Forest Department.

Finally, I wish to acknowledge my indebtedness to my friends Mr. B. M. Mukerji and Mr. Mitra, Demonstrators in Physical Science at the Thomason College, Roorkee, for the valuable assistance rendered in carrying out the combustions in this investigation.

CONTENTS.

The Selection System in Indian forests as exemplified in working plans based on this system, with a short description of some Continental methods

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Imperial Superintendent of Forest Working Plans

INTRODUCTION.

IN Indian high forests, generally abnormal in type, the selection system in one or other of its many modifications is nearly universally applied in Indian Working Plans, in calculating the possibility and prescribing the felling operations. The object of this monograph is, firstly, to bring together in a concise form the different modifications or methods which have sprung up in the various provinces of India, giving detailed examples from existing working plans; secondly, to contrast them; and finally, to indirectly indicate the advisability of prescribing a standard system for the whole of India for the calculation of the possibility by number of trees, and by the volumetric method respectively.

Part I.

THE SELECTION SYSTEM: GENERAL REMARKS.

PART I.

GENERAL REMARKS.

The factors which point to the application of the selection method of treatment to a forest under systematic management may be briefly summarised as follows: —

1. When the forest is stocked with shade-bearing species so that the young plants are able to tolerate shade and to persist under it for a protracted period of time.
2. When the complete natural regeneration of any given portion of the forest area cannot be brought about within a reasonable period of time.
3. When for any climatic or other reasons, the forest is growing under unfavourable or difficult conditions, so that it becomes dangerous or inadvisable to interrupt the cover.
4. When in a mixed forest, consisting of a number of species, only one of these is exploitable.

In the normal selection forest the individuals belonging to the different age classes are evenly distributed over the whole area, that is to say, in each portion of the forest are to be found individuals of all ages from the seedling to the exploitable tree. The question then naturally arises: What is the area which should be occupied by each of the age classes in the normal selection forest? And, what is the number of individuals which should be found in each of the normal age classes?

The normal condition of a forest under any regular system of working necessitates the presence of a series of age gradations corresponding to the number of years in the rotation, each occupying equal, separate areas: a condition which has always been held to be applicable to the selection method. It will however be readily admitted that this conclusion is in practice incorrect as far as it applies to the normal selection forest, since many of the individuals of the younger age classes are seen to be growing immediately beneath the older trees and are not therefore occupying separate areas.

Nevertheless in studying the constitution of the normal selection forest the above fundamental principle may for the present be accepted.

The impossibility of determining the age of the various individuals constituting the growing stock in a selection forest has led to the substitution of diameter- for age-classes. It is interesting therefore to consider what age periods the various diameter-classes may be presumed to represent.

Theoretical considerations, based on the laws of the development of the diameter in even-aged crops, which have grown up under the conditions therein prevailing, would point to the conclusion that the rate of diameter growth diminishes very considerably in the older age-classes. This however does not appear to be the case in a selection forest. It will be readily admitted that in such a forest the trees grow up under very different conditions, and that it is not necessarily the oldest trees that are represented in the highest diameter-classes: but those trees which have grown up under the most favourable conditions for their development. In Europe the conclusion now generally favoured appears to be that for any species the period passed in each diameter-class is the same; the trees in the highest diameter-class, if anything, growing (contrary to preconceived ideas) faster than those in the lower diameter-classes. And these conclusions appear to be borne out to some extent by such measurements as are available in India; though it must be remembered that few of the forests at present under observation in India have grown up even under approximately normal selection-forest conditions.

Table I.—Number of years passed in each diameter-class.

Province.	Forest Division.	Forest Reserve.	Number of years passed in each diameter-class.							Remarks.
			0″—4″	4″—8″	8″—12″	12″—16″	16″—20″	20″—24″	24″—28″	
Burma	Promo	Schwebe	...	19	18	20	24	27	25	Teak.
Punjab	Simla	Jubal State	15	13	12	13	15	16	16	Deodar.
,,	Kulu	Inner Suraj	18	14	15	13	15	24	15	,,
,,	,,	Outer Suraj	17	14	12	12	11	11	11	,,
,,	,,	Kulu	17	12	12	13	12	12	10	,,
,,	,,	Rupi	19	14	13	14	18	13	...	,,
Punjab	Simla	Jubal State	13	9	10	12	13	17	16	Pinus excelsa.
,,	Kulu	Inner Suraj	12	9	10	11	11	11	...	,,
,,	,,	Outer Suraj	14	11	10	9	11	11	10	,,
,,	,,	Kulu	15	11	8	9	10	11	...	,,
,,	,,	Rupi	12	8	9	10	13	13	15	,,
North-West Frontier Province	Hazara	Siran	13	12	12	14	17	21	...	Pinus longifolia.

Table II.—Number of years passed in each girth-class.

Province.	Forest Division.	Forest Reserve.	Number of years passed in each girth-class.							Remarks.
			0′–1′	1′—2′	2′—3′	3′—4′	4′—5′	5′—6′	6′—7′	
Burma	Rangoon	Rangoon Hills	25	18	19	20	22	20	20	Teak.
,,	Tharrawaddy	Sitkwin	28	12	12	11	18	17	...	,,
,,	,,	Thindayo	28	17	18	21	15	12	...	,,
,,	,,	Sitkwin, Thindayo	29	15	16	14	17	...	...	,,
,,	,,	South Zamayi	23	17	19	21	23	24	28	,,

It will readily be admitted that the number of trees which should be found in each normal diameter-class must increase considerably in each successive lower class. That is to say, to produce "*n*" first class trees it will require more than "*n*" second class trees and a far greater number of third class trees; and so on. But the exact proportion between the number of trees to be found in each successive diameter-class in a normal selection forest still remains undetermined. The view most recently expressed in France, from the study of all available data collected with the object of solving this very question, appears to be that there exists for each forest a constant ratio between the number of trees in the successive diameter-classes. That is to say, if "x" be the constant, there will be required in the normal selection forest in order to produce one first class tree, x, 2nd class trees; x^2, 3rd class trees; x^3, 4th class trees; and so on. And this constant is said to vary in the different French selection forests between 1·25 and 1·45, for diameter classes differing by 5 centimeters.

It is difficult to say how far these figures are applicable to India; as so far, with one exception, no attempt appears to have been made to arrive at a conception of the constitution of the normal selection forest from the study of existing forests.* The one exception above referred to relates to certain figures noted by Mr. F. A. Leete, I.F.S., in his working plan for the sâl forests of the Kheri Division, and these yield the following results (the diameter-classes being unfortunately extremely large).

Girth.	Number of trees in a normal series.	Ratio between the number of trees in successive girth classes of a normal series.
6′ & over	1	......
4½′—6′ . . .	1·23	1·23
3′—4½′	1·61	1·30

Again turning to the average number of sâl stems of different girth-classes found to exist in such sâl forests as have been enumerated, the following results are obtained:—†

* Vol. II of Huffel's "Economic Forestiere" should be consulted on this subject. It cannot be said that Prof. Huffel's figures are altogether convincing; but they may be accepted as forming an interesting basis of investigation.

† See page 205 of Indian Forest Records, Vol. I, Part I, Calcutta: Superintendent of Government Printing, India.

Girth.	Average number of trees obtained by actual enumeration.	Ratio between the number of trees in successive girth classes.
Over 6′	1	......
$4\frac{1}{2}'$—6′	2·84	2·84
3′—$4\frac{1}{2}'$	8·10	2·85

Theoretically the whole area of a selection forest should be worked over annually in order to obtain the material annually becoming exploitable. In practice this procedure is for obvious reasons impracticable and inexpedient. On the one hand, it is impossible to work over too large an area yearly; on the other hand, it is inexpedient for cultural and other reasons to work over the same area at too frequent intervals. The practice has in consequence arisen of fixing a so-called "*felling rotation*" during which period the forest is worked over in regular order.

The various arguments which may be taken into consideration in fixing the felling rotation may be summarised as follows:—

1. The felling rotation must be short in order to permit of the extraction of deteriorating trees before these lose their value.
2. The length of the felling rotation must be sufficient to repair all damages which may have been caused in felling over the area and in extracting the produce.
3. A very short felling rotation may give too large felling areas, and thus inordinately increase the cost of extraction.
4. A short felling rotation may necessitate too frequent re-enumerations, which unnecessarily increase expenditure.
5. A long felling rotation leads to too heavy an exploitation in each felling area. If 4 per cent. of the growing stock represents the possibility of the whole area, 20 per cent. would be extracted over each portion of the area with a 5-year felling rotation; and 60 per cent. with a 15-year felling rotation.

These and similar considerations would probably point to a felling rotation of 8 to 12 years as the most suitable one. Or, to put it in the form of a general rule (a rule which has found great favour amongst European foresters): *The length of the felling rotation should be at least equal to the time taken for the crop to pass through one girth class.*

The size of the girth classes will naturally largely influence this period; but it will also be found that certain other expedients may frequently be usefully employed, the better to enforce the rule above enunciated. Thus, the whole of the forest may be worked over twice during the course of the felling rotation; or, the richer portions of the area may be worked over twice and the poorer portions once. Or, the forest may be divided up into a suitable number of felling series with obvious advantages.

The introduction of a felling rotation and the division of the area into a number of annual coupes, each of which is expected in its turn to yield the possibility of the whole area, naturally brings about certain abnormalities. In the first place, the constitution of the selection forest is thereby considerably altered; it is evident that it must assume a condition intermediate between the true selection type and the regular type of forest, approaching nearer to the latter condition as the felling rotation is increased.* Again, if the area of the coupes is fixed, since in practice the stocking must necessarily vary considerably in different parts of the area, it follows that too much will be removed from one coupe, too little from another; and, when the possibility is by volume, it will become impossible to make any distinction between the *final* and *intermediate* yields of the forest, the possibility being made up as best it can from either or both kinds of produce. Considerable difficulty will invariably be experienced in marking for fellings in a selection forest when the annual yield of the whole forest has to be obtained from a fixed coupe, an operation which leads to unsatisfactory and uneven marking: either the end of the coupe being reached without having obtained the prescribed possibility, or a certain proportion of the area remaining unmarked.

* Eventually if the felling rotation becomes equal to the exploitable age the forest would assume the constitution of a regular forest. See also pages 227 and 238, Schlich's Manual of Forestry, Volume III.

These inconveniences may to a certain extent be avoided—(1) by calculating the yield to be obtained from each coupe separately; this yield being based on the possibility of the whole forest. That is to say, if the possibility be fixed at (say) 1·33 per cent. of the total material on the entire area of the forests, with a 10 years felling rotation, 13·3 per cent. of the actual material calculated separately for each coupe would be removed from that coupe.* Or, (2) the boundaries of the annual coupes are not fixed; the forest is worked over systematically from end to end, the fellings being stopped annually as soon as the possibility, based on the yield of the entire area, has been obtained. Under this arrangement, which is bound to give very uneven results, it will always be found expedient to divide the entire area into a fairly large number of compartments so that by stopping the fellings at suitable boundaries, order may be maintained in the working.

* See page 93, D'Arcy's Preparation of Forest Working Plans in India, 3rd Edition.

Part II.

FIXING THE POSSIBILITY.

1. Possibility by Area.
2. Possibility by Number of Trees.
3. Possibility by Volume.

PART II.

FIXING THE POSSIBILITY.

The possibility in a selection-worked forest may be fixed either by area, by number of trees, or by volume.

SECTION 1.—POSSIBILITY BY AREA.

The felling rotation and the size and position of the felling areas (or coupes) having been fixed in accordance with the considerations set forth in the preceding section,* each coupe is worked over in turn at the discretion of the marking officer, the fellings being limited purely by cultural rules. It is evident that this method can only be considered as a purely temporary makeshift if the object of management is to bring the forest into the normal condition, that is, if the constitution of the crop is to be such that the forest will yield an equal annual sustained yield. It is unnecessary to lay stress on the impossibility of attempting to estimate by eye the possibility of a selection forest, and subsequently to apply that imaginary yield in carrying out the markings in the annual coupes. Indeed, the method is only admissible under certain special conditions, which unfortunately only too frequently occur in India. Such a procedure may be permissible in the case of a protection forest where the object of management is a desire to retain the cover, dead and dying trees alone being removed: or, in abnormal and partially-ruined forests, such as frequently occur in India, in which the higher girth classes are very poorly represented in numbers and in quality: or, when the object of management is purely to tend the crop and to exploit the dead, dying and over-mature trees, whilst allowing the forest to grow up,† etc.

Unfortunately the method of areas for selection forests, owing to its paper-simplicity, and the consequent expeditiousness with which working plans can be drawn up, especially when an equal annual return even during the period of the felling rotation is not attempted, has lately received considerable support in India. The

* See page 37.

† In parts of India such selection fellings are classed as fellings under the method of Improvement Fellings.

arguments in favour of such a scheme have been very fully set forth in various articles published in the "Indian Forester," (*vide* Volume XXXIII, page 224; XXXIII, 282; XXXIII, 366; XXXIII, 422).

Though the method of fixing the possibility herein dealt with has been termed *the method by area*, in that the annual selection fellings are invariably confined to a portion of the whole forest, yet it would perhaps be more correct to describe it as a method by cultural rules limited by prescribing the minimum girth or diameter of the trees to be felled.

In its normal form, the forest having been divided into a convenient number of felling areas, in the manner previously described, one coupe would be worked over annually, the amount of material to be removed being limited by cultural rules, and by restricting the fellings to the removal, here and there within the coupe of the year, according to the principles of the selection method, of such trees as are over-mature or are above a certain girth.*

Bearing in mind the cases in which the fellings may properly be regulated by the method of areas, it is obvious that the procedure will very greatly differ according to the intensity of the demand on the forests. Thus, where the demand is fluctuating and at all times insignificant and far below the real possibility of the forest, it is evidently unnecessary to fix the limits of the annual coupes; and fellings of mature trees may be permitted in any convenient portion of the forest. On the other hand, when there is a demand for a fixed yield, the annual coupes would be made proportionate to their yield capacity, and the number of these would, if possible, correspond to the number of years taken for the crop to pass through one girth class. In addition a rough estimate of the crop could also be made. Between these two limits, intermediate stages will naturally occur in which the stocking is poor (particularly as regards the

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* "But the method enforced in the manner explained above is attended with "the drawback that there is no means, other than by personal inspection, of check- "ing its correct application. The only extraneous control that can be exercised "over its application is with regard to the *area* exploited; and all the prescriptions "on this subject might be rigidly adhered to while the far more important cultural "rules were being misapplied by unintelligent or unscrupulous subordinate officials. "Hence, where possible, it is always preferable to determine the quantity of "material that may annually or periodically be removed with safety, and to limit "the fellings to this maximum quantity while subordinating them to cultural "rules."—*D'Arcy's Preparation of Forest Working Plans in India, 3rd Edition, page 83.*

older age classes) and only justifies the removal of a proportion of the exploitable trees in each annual felling area, say one-half or one-quarter of the available trees. The examples given below, taken from working plans in force in various parts of India and Burma, will show the procedure which has been followed under definite conditions.

Example 1. Demand insignificant and uncertain. Area of coupe undefined.

Thus, in the case of the Surai-Banbasa forests of the Pilibhit Division, United Provinces,* the working-plan prescriptions read as follows:—

It is proposed to treat this area of miscellaneous species by Selection, felling trees as they reach the girths which are thought to represent the commercial maturity of each species provided that the trees felled are not so situated that a regrowth in their place is not possible. The felling too will depend on the demand, and mature trees will not be removed unless there is a purchaser for them. They may be cut anywhere in the Circle at any time.

The fellings will be restricted to the limits of size at which the several species are believed to become mature approximately. The demand is likely to be small, and the area being small also, no division into coupes is required.

Fellings of mature trees may take place at any point at any time during the ten years of this plan.

Selection fellings, regulated by the girth measurements at which the various species stocking the Working Circle are believed to become mature, have been prescribed. The following will be the girth measurements at, or above which, the species in demand may be selected for felling :—

Name of species.	Girth at four feet from the ground.
Khair, kari, pula, dholdhak, amaltas, kumbi, asid, chilla, gurgia, maini, tendu, dudhi, bhurbula, khaja, bel, bhilawa, aonla	4 feet.
Shisham, jhigna, paira, dhak, maulia, kachnar	5 „
Haldu	7 „
All other tree-size species	6 „

The trees may be felled in any year at any part of the area, but those in blanks too large to be regenerated from the surrounding forest should be spared.

Example 2. Felling rotation arbitrarily fixed.

In the method by area, the division of the forest into suitable felling areas is always a matter of importance. The felling rotation may as in the case of the Working Plan for the

* Working Plan for the Surai-Banbasa forests, Pilibhit Division, United Provinces, by Pandit Sadanand Gairola, Provincial Forest Service, 1902.

Rangoon Plains forests, Burma,* be made merely to yield coupes of a workable size.

The Rangoon Plains forests have been considerably over-worked in the past, especially as regards *pyinkado*, and the main object to be obtained is the production of a sustained yield of as much timber and fuel as possible, consistent with the improvement of the forests.

The system to be adopted must be the selection method. Except as an experiment it is not advisable to adopt the coppice with standards system because most of the species do not coppice well and interruption of the cover of considerable area results at once in a dense growth of coarse grass against which seedlings have very little chance. Small areas of 20 acres each will be selected in compartment 1 of the South Hlaing Yoma block and worked on the system of coppice with standards. The rate of growth of the various species differs considerably and very little is known about it. Some countings of rings on stumps were made but they are hardly sufficient to accurately ascertain the rate of growth. The whole area will be worked in 20 years, at the end of which period something more may be known about the rate of growth and exploitable age of the various species.

There are at present insufficient data for determining the age of exploitability of the various species. From the above data it would seem that the rate of growth of *teak* and *pyinma* is about the same whilst that of *eng* and *kanyin* is quicker and that of *pyinkado* considerably slower. The question of rotation must therefore be left open until more details can be obtained. A felling rotation of 20 years will be prescribed during which felling operations will extend over the whole area.

The forests are very uneven in character, the greater portion consisting of mixed forests in which *pyinma* (*Lagerstrœmia flosregina*) and *kanyin* (*Dipterocarpus alatus and lævis*) are common along streams and in moist localities, and a mixture of many other species elsewhere.

Fairly extensive areas of *indaing* occur, and in places *teak* and *pyinkado* occur and grow fairly well. Such areas are comparatively small and quite local in extent. The relative density of teak as compared with some other reserves in Lower Burma is as follows :—

Rangoon Plains forests	·015
Kabaung reserve, Toungoo Division	·105
Bondaung reserve, Toungoo Division	·208
Nawin reserve, Prome Division (mean of 4 Working Circles)	·162
Gwethe reserve, Toungoo Division	·058

It is thus seen that the relative density of teak is very small. The crop consists chiefly of mixed species, and, with few exceptions, everything the area produces is or soon will be saleable. The selection method is therefore the only one which commends itself. As a rule the younger classes of all species are well represented and it is advisable to encourage their growth by fire-protection and improvement fellings in order to obtain an increase in the quality and quantity of timber and fuel.

The whole area will be worked over once in 20 years. The fellings will be by area and will be of two kinds :—

(*a*) Fellings of mature trees.
(*b*) Improvement fellings.

* Working Plan for the Plains forests, Rangoon Forest Division, Pegu Circle, Lower Burma, by J. J. Borie, I.F.S., 1905.

They will be made simultaneously as in that way the work will be more concentrated.

(*a*) *Felling of mature trees.*—The most valuable species are :—

Teak, pyinkado, eng, ingyin, thitya, pyinma, kanyin, thitka, thingan, seikkyi, myaukkyaw, zinbyun, and taukkyan. The last named three species are in great demand for fuel, especially *myaukkyaw* which sells for nearly twice as much as any other species. With the exception of *pyinkado* and *kanyin* all species may be regarded as mature when they have reached a girth of 6 feet, measured at breast height and may be felled whenever found, unless it is desirable for sylvicultural reasons to leave them standing. As regards *pyinkado* and *kanyin*, the girth limit is fixed at 7 feet and 8 feet respectively. The areas prescribed to be worked annually have been so arranged as to distribute the timber and fuel at various centres along the railway line, and thus meet all requirements. Each coupe will be kept open for 2 years so as to permit of the maximum extraction of timber, fuel and charcoal.

The following particular rules should be observed—

(1) When trees show sign of premature decay and would, in the opinion of the executive officer, lose their value if left, they may be felled at once even if they have not attained the prescribed dimensions.

(2) Isolated trees should not be felled unless a crop of seedlings already exists on the ground, and it is desirable to clear away the cover from them.

(3) Dead trees should be worked out along with green trees marked on the areas.

(*b*) *Improvement fellings.*—These will be carried out annually in the usual way at the same time and over the same areas prescribed for fellings. The object will be to assist the best species whether valuable for timber or fuel.

The total area of the working circle is 53,014 acres including 1,858 acres of plantations in the Magayi plantation area. This leaves a balance of 51,156 acres to be worked over in 20 years. The average annual coupe is therefore 51,156 $\times \frac{1}{20}$, or 2,558 acres.

The determination of the annual yield is rendered very complicated by the extreme irregularity of the forest and the varying rates of growth of the numerous component species. It is estimated that with the exception of *pyinkado* and *kanyin*, two-thirds of the mature trees of all species (*i.e.*, trees of 6 feet girth and above) will be felled. In the case of *pyinkado* and *kanyin* the girth limit is 7 feet and 8 feet respectively. No counting of trees of this girth were made, the field work having been completed before the Preliminary Working Plan was sanctioned. It will, I think, be safe to assume that one-third of the *pyinkado* and *kanyin* shown under the class "6 feet in girth and above" are of the required girth limit of 7 feet and 8 feet respectively and calculations will be made accordingly.

The annual yield must vary considerably owing to the irregularity of the forests, and it is only proposed to estimate the average annual yield during the first 20 years' felling rotation.

According to para. 27 the number of trees of all species 6 feet in girth and above is :—

Teak	3,604
Pyinkado	5,702
Pyinma	15,507
Kanyin	7,423
Eng	17,644
All others	175,135

Assuming that one-third of the *pyinkado* and *kanyin* and two-thirds of all the other species will be removed during the 20 years' felling rotation, the average annual yield will be :—

Teak	3,604	or	120
Pyinkado	5,708	,,	95
Pyinma	15,507	,,	517
Kanyin	7,423	,,	124
Eng	17,644	,,	588
All others	175,135	,,	5,838

This is a very rough estimate, but no accurate data are yet obtainable to calculate how long it takes the various species to pass from Class II into Class I. The annual yield will be larger towards the end of the felling rotation as a proportion of trees under 6 feet in girth will, by that time, have reached the prescribed girth and become mature.

The fellings are only prescribed for 20 years at the end of which time it will be necessary to revise and probably alter the plan.

Example 3. Felling rotation =number of years passed in penultimate girth class.

In other cases, the felling rotation may with considerable advantage be made equal to the number of years required for the second class tree to reach commercial maturity, as has been done in the working plan for the Samta forests of the Singhbhum Division, Bengal.*

These forests should obviously be worked with a view to obtaining large timber for sleepers, boat construction, houses, etc.

In view of the facts that we are not quite sure of the rate of growth (the data being insufficient), that we have no figures of the total number of trees in the several classes, and that much of the hill sâl is unfit for working, it has been decided to limit the fellings by area, especially by the area of the Valley type, which is the only part of the crop likely to yield important quantities of marketable timber, and to remove from each coupe all trees over 6 feet in girth.

From what has been stated regarding the rate of growth, it appears that in Valley type areas most of the sâl trees which are at present 5 feet to 6 feet in girth will become over 6 feet in girth in 30 years; and from the valuation surveys and from general observation it is clear that the number of trees which are now 5 feet to 6 feet in girth exceeds the number of trees which are now over 6 feet, and that trees between 4 feet and 5 feet are more numerous than those between 5 feet and 6 feet girth. Hence it appears quite safe to adopt a felling rotation of 30 years removing all trees over 6 feet in girth from each coupe as it is worked.

The difficult nature of the country, making it impracticable to mark over very large areas annually, taken with the existing defective state of the communications, renders it impossible to work over the whole area of the forests in a period much less than 30 years, and 30 years is hence adopted as the length of the felling rotation.

The period for which fellings are prescribed is however half of the felling rotation, *i.e.*, 15 years.

It is intended that a revision of the plan shall be undertaken after 15 years.

* Working Plan for the reserved forests of the Singhbhum Division, Bengal, by H. H. Haines, I.F.S., 1906.

The annual coupe will consist in approximately 1/30th of the Valley type area in addition to the areas of such other crops as fall within the limits of the compartment or compartments in which such area of Valley type is situated. The order of the fellings is regulated by the course of the export roads existing or prescribed, this in its turn being mainly determined by the position of the areas containing the largest number of mature trees.

The trees are to be marked for felling on the principle of the method of selection fellings, including the following conditions :—

(i) No sound sâl tree under 6 feet in girth at 4 feet from the ground may be felled, unless the tree has a broken stem, or is bereft of large branches which have torn the stem in falling.

(ii) Sâl trees under 6 feet girth which are dead hollow, stag-headed, or diseased may be marked for felling, but only under the closest supervision.*

(iii) Sound sâl trees of 6 feet and over should not be felled so close together as to cause large blanks. In those compartments containing forest with numerous mature trees (*vide* para. 35 and Appendix 1), special caution must be exercised and a number of first class trees must be left.

(iv) Trees should not be felled when they stand over heavy grass without advance growth.

Lastly, the condition of the stock may necessitate the reservation for sylvicultural reasons of a proportion of the available mature or exploitable trees: and the number so reserved may amount to one-half or one-quarter of the whole stock of exploitable trees found standing in each felling area.

Example 4. Stock very poor. One-half of available mature trees reserved.

Thus, for reasons fully explained below in prescribing the working of the Tulsipur reserved forests,† United Provinces, by the selection method, the removal of only one-half of the mature timber which is exploitable has been considered expedient.

The growing stock is of such irregularity and, over a large part of the area, of so little commercial value, that no valuation by enumeration surveys or otherwise was attempted. Moreover, the method of treatment adopted does not render necessary any more precise analysis of the crop than that contained in Chapter II, Part I, and in a very detailed description of compartments.

An estimate has been formed, for each compartment, of the area covered by each of the principal species. These areas have been worked out from stock maps on the 4-inch scale, prepared by an eye-survey, and given with a short description of the crop in an Appendix.

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* "This rule is necessary. The words 'diseased,' 'stag-headed,' 'dying' are used by certain executive officers as an excuse to mark almost any tree required by purchaser, and a week or two after felling controlling officers are unable to say positively that the tree was not in one of these conditions."

† Working Plan for the Tulsipur forests of the Gonda Division, United Provinces, by F. F. R. Channer, I.F.S., 1902.

It has been shown that the Tulsipur forests contain but little valuable timber, and owing to the nature of the ground there is not much prospect of any considerable improvement in this direction. But the forests are of great utility in supplying the wants (including grazing) of the surrounding population; and their position at the foot of the barren Nepal hills renders their careful preservation a matter of vital importance.

Under these circumstances the object sought to be attained must be two-fold :—

(*a*) To increase the area under forest and improve the quality of the growing stock, and at the same time to maintain a regular supply of such produce as is required by the surrounding villages, both privileged and non-privileged, and of the larger classes of timber for the more distant markets.

(*b*) To provide for the cattle of the privileged villages to the satisfaction of the villagers, with a minimum of damage to the forests and hindrance to the realisation of the above objects.

With the objects mentioned in the preceding section in view, selection fellings based on sylvicultural requirements are prescribed for the whole of the closed forests, and under this system mature trees of all species will be removed.

The selection fellings will be followed in each coupe by cleanings, which will take place twice during the rotation.

Selection fellings.—Since the fellings are based entirely on sylvicultural requirements, the calculation of the exploitable age is unnecessary, and it will be sufficient if the girth at which each of the more important species become mature is laid down. This will, of course, differ according to the locality, but from observations made in the more favourable situations the following assumptions may be made :—

Sâl attains maturity at a girth of	. . . . .	5′ 6″
Dhao ,, ,, ,,	. . . . .	6′ 0″
Asna ,, ,, ,,	. . . . .	6′ 0″
Shishan ,, ,, ,,	. . . . .	6 0″
Haldu ,, ,, ,,	. . . . .	7′ 0″
Khair ,, ,, ,,	. . . . .	4′ 0″
Miscellaneous species ,,	. . . . .	6′ 0″

Half the mature timber which is exploitable, having regard to the density of the crop and the state of regeneration, will be removed by the selection fellings during the felling rotation. These fellings will put a regular supply of large trees on the market. In each annual coupe the selection fellings will be followed by cleanings which will include the felling of inferior trees of all sizes, the removal of which will benefit the growing stock, and the thinning out of pole forests. These latter fellings will have to supply the wants of the privileged villagers and the balance over will be available for the local markets. They will be repeated in each coupe after ten years. Owing to the extreme irregularity of the forests and the absence of any valuation of the crop no calculation of the possibility is practicable.

Each circle has been divided into 20 annual coupes.

Half the mature trees, *i.e.*, the more mature half, according to the girths fixed above of all species, will be removed provided that no permanent blanks are thus created. There should be little difficulty in executing these fellings satisfactorily. On the high and broken land mentioned in Part I, as being

covered with stunted growth, no felling should take place, and where the sâl is not well represented, even mature trees should be left standing.

Example 5. One-quarter only of exploitable mature trees to be removed.

Again, in the case of the Nambor forests, Assam,* it was found necessary to restrict the selection fellings to one-quarter of the stock of exploitable mature trees.

The felling rotation adopted is 15 years, *viz.*, half the time believed to be taken by a Nahor tree† of the 2nd class (4′ 6″ in girth) to reach the first class (6 feet in girth and over). As the trees have not been enumerated, the possibility has been fixed by area only and not by number of trees or volume. The area has been divided into 15 annual coupes which, to avoid the labour and expense of cutting many additional artificial lines, have been made coterminous with the 15 compartments into which the forest is at present divided by existing natural or artificial boundaries.

It is believed that a period of 30 years is required for a Nahor tree of the second class to reach the first class. The felling rotation adopted is 15 years, as a shorter felling rotation would result in the annual coupes being inconveniently large. Under normal circumstances the fellings would be prescribed for one whole felling rotation. But as compartments 9, 10, 11, 12, 13, 14, and 15 have been already heavily felled over, it has not been considered safe to prescribe fellings again in these compartments as concerns Nahor until it is seen how far they have recovered from the recent fellings. Accordingly, the fellings have been prescribed for 8 years only and in such compartments as have been not at all or only slightly indented on up to date. At the end of the 8 years it will be possible to judge if the compartments mentioned can be safely felled over again, or if it will be expedient to leave them as concerns Nahor till the end of the second felling rotation.

The possibility of the different compartments in number of trees not being known, no attempt to equalise the yield could be made. It seemed, therefore, desirable to make the annual coupes coincident with the 15 compartments into which the area naturally falls under the existing system of roads and paths, streams and rivers, without making any attempt to equalise the area of the annual coupes. Each compartment, therefore, forms an annual coupe, and the numbers of the compartments indicate the order in which the fellings should normally be conducted subject to the remarks made in the preceding paragraph.

At the end of the first felling rotation sufficient data for the calculation of the possibility will be forthcoming, and it will then no doubt be found necessary to re-arrange the coupes so as to equalise the yield.

The trees are to be felled according to the principles of the method of selection fellings. As the felling rotation has been fixed at 15 years (half the period necessary for trees of the second to reach the first class), only one-half of the exploitable trees in each coupe could under any circumstances be marked for felling. But as it is uncertain whether these portions of compartments 9 to 15 which have been already felled over during 1901-1903 will be in a condition to be felled over again during the first felling rotation (and if not, compartments 1-8 would have to be again felled over during the years 1912 to 1918), it is

* Working Plan for the Nambor reserved forest, Sibsagar Division, Assam, by A. R. Dicks, I.F.S., 1906.

† *Mesua ferrea.*

proposed to restrict the fellings of sound Nahor trees 6 feet in girth and over during the first eight years to one-fourth of the total number of such trees in compartments 1-8. The only way to secure the observance of this restriction with the present untrained staff is to provide that for every sound Nahor tree 6 feet in girth and over for felling, three such trees must be marked for reservation. Accordingly, the marking of Nahor trees for felling in compartments 1-8 is subject to the following conditions :—

(1) Before any sound Nahor trees are marked, all dead, dying, and unsound trees over 4 feet in girth must be marked for felling.

(2) No sound Nahor trees below 6 feet in girth may be marked for felling.

(3) No isolated sound Nahor tree 6 feet in girth or over may be marked for felling if there is no young growth coming up round it.

(4) For every sound Nahor tree 6 feet in girth and over marked for felling, three such trees must be marked for reservation.

SECTION 2.—POSSIBILITY BY NUMBER OF TREES.

The main disadvantage of prescribing a possibility by number of trees lies in an unequal return: and on this account the method has been almost wholly discarded in Europe. The impossibility of fixing a yield by number of trees which would include both primary and intermediate produce (as can be done with a volume possibility) is only too apparent; and even if a girth be arbitrarily fixed (as is usually done) in order to separate the Final Yield (counting against the possibility) from the Intermediate Yield, the returns must still vary considerably, especially since the girth so fixed must frequently vary with the species and with the locality.

Nevertheless under the conditions usually prevailing in India a possibility fixed by number of trees is the only practical one. In the first place, its greater simplicity highly commends it: but, in addition, when as is usually the case only trees of large size are saleable; when only one species in a mixed forest is exploitable; when the establishment is small, untrained, and the cost of valuation surveys is prohibitive; when an absolutely equal yearly volume return is not desired, a possibility by number of trees appears to fully meet all such requirements.

The possibility by number of trees may be calculated in a variety of different ways. Many of these methods have been devised in India to meet local conditions, and though these may differ only to

a very slight extent, it will be found possible to recognise the following: —

i.—Brandis' Method.
ii.—The Oudh Method.
iii.—The General Possibility Method.
iv.—The Burma Method.
v.—The Crown Cover Method.
vi.—Possibility based on the normal forest.

It is perhaps unnecessary to point out that many of these methods are not altogether theoretically correct. Nevertheless they are sufficiently accurate for all practical purposes under the conditions frequently prevailing in India where large areas have to be dealt with in a short time, and with an inadequate and partly untrained establishment.

A question which however appears to have been frequently overlooked in India is that the distinction between the various Indian methods (*i.e.*, Methods i to iv above) lies chiefly in correctly realising the rotation on which the forest is being worked, that is, the exploitable age of the trees counting against the possibility. It is evident that in any given forest, the possibility of which has been calculated under Brandis' Method, the rotation will be a longer one than under the Burma Method. For instance, to take a concrete case, suppose the minimum exploitable girth be 6 feet, which represents an age of 100 years, and that the length of the felling rotation be 15 years (the number of years required to pass through a girth class); it follows that, in the normally constituted forest, under Brandis' Method the average age of the tree felled during each felling period would be 115 years; as compared with 108 years, the average age under the Burma Method. But this is not all, for though 100 years (as represented by a girth of 6 feet) would be the age of the lowest exploitable tree under both Methods, in Brandis' Method in the normally constituted forest trees varying in age between 100 and 130 years (with corresponding girths) would be obtained, whereas under the Burma Method the age of the trees felled would vary in the normal forest merely between 100 and 114 years of age. And the same argument applies whatever may be the length of the felling rotation.*

* See also "*Indian Forester*," Volume XXXIII, page 185.

It is also evident that when the possibility under the Oudh Method is taken to be equal to the whole of the Class I trees *plus* ½ the Class II trees, that the yield so calculated will be identical with that which would be obtained by the Burma Method, when the possibility is calculated for a period equal to the number of years taken for a tree of the lowest dimensions of Class II to attain the lowest exploitable dimensions.

Furthermore under Brandis' Method when the felling rotation is a long one, the maximum age of the trees may be so raised as to cause serious deterioration by the time their turn comes to be harvested.

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i.—Brandis' Method.

In Brandis' Method the possibility is based on the number of exploitable or Class I trees existing in the forest; it being permissible to remove the whole of these in the time which it takes to replace them. In calculating the possibility it will be necessary then to ascertain—

(i) the number of first class trees in the forest; and
(ii) the number of years it takes to replace them.

By dividing the former figure by the latter, the maximum number of trees which it may be possible (subject to sylvicultural considerations) to cut annually is determined.

Thus, suppose the rotation be fixed at 100 years, which under the selection system is represented by a tree 6 feet in girth (the minimum exploitable girth). And suppose the enumeration of the forest has been carried out in 6-inch girth classes, and that it has been ascertained that each girth class represents a period of 15 years. Then, *in the normally constituted forest,* at the commencement of the felling rotation of 15 years, the age of trees in the Class I would vary between 101 and 115, and that of the trees in girth Class II between 86—100 and so on. The trees in Class I present at the commencement of operations are exploited during the period of 15 years; it follows that in the first year trees 101—115 will be obtained, in the second year trees between 102—116, etc., etc., and in the last year the age of the trees will be 116—130, which gives an average age of 115 years.

An example taken from a Working Plan recently compiled will perhaps best explain the method of procedure.

In the case of the Motinala forests of the Mandla Division, Central Provinces, the exploitable tree has been defined as one with a minimum girth of 6 feet breats high. It has also been calculated that a tree with a girth of 5 feet becomes exploitable, that is, attains a girth of 6 feet, in a period of 30 years. The enumeration surveys give the following results, *viz.* :—

	Number of trees.
Class I, above 6′ in girth	25,431
,, II, 5′ to 6′ ,, ...	47,148
,, III, $4\frac{1}{2}'$ to 5′ ,, ...	61,859
Total .	134,438

Bearing these figures in mind, the following extract will explain the manner of calculating the possibility.

It has been determined . . . . that trees of 6 feet in girth throughout the forest are exploitable. The removal of these trees will be spread over a period of 30 years, the time required for a 5 feet girth tree to attain a girth of 6 feet. In other words, the number of I Class trees which may be removed annually is :—

$$\frac{\text{The total enumerated number of I Class trees}}{\text{The number of years required to replace them}} \text{ or } \frac{25{,}431}{30} = 847.$$

It is evident that the possibility so calculated will require modification according to the present condition of the growing stock. On the one hand the full possibility as above calculated under this method may be increased by the number of trees in the girth classes immediately following, that is, in Classes II and III, which it may be calculated will never survive to reach the exploitable girth. On the other hand, it may be found necessary owing to the forests being poorly stocked, or owing to the higher girth classes being badly represented, to reduce by a suitable amount the annual possibility as above calculated. A few examples will explain the method of procedure.

Example I. A proportion only of I Class trees are removed during the first felling rotation.

In the Oak High Forest Circle of the Kangra Forest Division, Punjab,* it was calculated that the time necessary for an Oak of 4 feet girth to attain a 5′ 0″ girth (the exploitable size)

* Working Plan for the Kangra Forest Division, Punjab, 1905, by G. S. Hart, I.F.S.

is 30 years; and the enumeration surveys gave the following results:—

Forests.	Number of I Class trees over 5′ girth.	Number of II Class trees 4′ to 5′.
Palampur series	16,426	10,685
Kanyara series	2,495	2,128
Narwana-Chandarban series	8,601	1,978
	27,522	14,791

In some of these forests, notably in Narwana and Chandarban, the second class trees are not in proper proportion, and so, in order to be on the safe side, it is proposed to limit the yield during the period with which the Plan is concerned to from one-third to two-thirds of the present stock of trees of exploitable dimensions; the proportion of the stock to be felled being determined with due regard to the incidence of the grazing rights (closed or open to grazing) and the condition of the crop. Nine-tenths of the area comprising the Palampur series is open to grazing, portions of some of the forests have been rather heavily worked in the past, and the regeneration is not very good; consequently the fellings have been limited to the removal of rather less than one-third of the mature stock. The Kanyara series is also open to grazing, but the regeneration is good and the proportion of second class stems fairly satisfactory, so that two-fifths of the mature trees can be cut without fear. Narwana-Chandarban also is open to grazing and the proportion of second class stems is very deficient; but the regeneration is excellent and justifies the removal of two-fifths of the first class trees. The yield fixed for each forest, compartment or sub-compartment, is given in the table of fellings.

Again, in the case of the deodar forests of the Bashahr* Division we read as follows:—

It is believed that to propose the removal of the whole of the first class stock during the period in which the second class will reach maturity would be too drastic, more especially as this course would probably result in having to reduce the exploitable size to 6 feet in girth, which is inadvisable, and in having to face a large reduction in the yield at the close of the period with which the plan is concerned. It is proposed therefore to leave in each felling series an average of one existing first class tree per acre of workable forest at the end of the period necessary for the present second class trees to become first class, and to cut the remainder of the present first class in the number of

* Revised Working Plan of the Bashahr Leased Sutlej Valley forests, Punjab, 1905, by G. S. Hart, I.F.S., and A. J. Gibson, I.F.S.

years comprised in that period. The yield calculated in this manner is shown in the following statement :—

Felling series.	I Class Deodar.	Period required for II Class trees to become I Class.	Maximum possibility calculated by Brandis' Method.	Annual yield calculated after deductions of one I Class tree per acre.
Chini	20,738	50	414	367
Kailas	41,974	40	1,049	922
Kilba	32,752	30	1,091	878
Taranda	15,094	25	603	419
Pandrabis	33,557	30	1,118	772
TOTAL	...	...	4,275	3,358

Example II. All sound I Class trees *plus* unsound II Class trees.

In addition to the maximum possibility as calculated by Brandis' Method, it is evidently permissible to remove all unsound trees of the second and lower classes, as well as such other trees of these classes as it is calculated will for various reasons never attain exploitable dimensions.

The following example illustrating the first case is instructive as showing not only the manner in which the removal of the unsound Class II trees may be prescribed, but more especially the method in which a forecast of the condition of the crop at the conclusion of the fellings may be calculated.*

Owing to the forest being in such an abnormal condition and to the great number of unsound trees, it is proposed for the first felling rotation to cut over all the Class I teak and the unsound trees of Class II by the selection method.

The period proposed for this felling rotation is 40 years, or about two-thirds of the time it takes a Class II teak to become Class I.

From the valuation surveys it is estimated that the present stock of teak is as follows :—

Class.	Sound.	Unsound.	REMARKS.
I	6,465	26,941	*N.B.*—Crooked worthless trees are included with unsound.
II	21,386	44,830	
III	43,125	76,055	
IV	52,698	96,500	

* The notes following are extracted from the Working Plan for the Allapilli forests, Chanda Division, Central Provinces, by P. H. Clutterbuck, I.F.S.

It will be noticed from the above table that the number of sound Class I teak is very small. This is due to the fact that the forest was leased out by the Ahiri Zamindar to contractors prior to its sale to Government, and these contractors cut out as many of the large sound trees as they could obtain. It will be a very long period before the stock will be again in a normal condition. as the only really large age class is Class V, below 6 inches diameter, which is a direct result of fire-protection and general conservancy by the Department. This class was not enumerated in the valuation surveys just undertaken, but it contains at least 500,000 trees at present, and will become much greater after this felling rotation is over and the whole area has been regularly treated.

Taking only sound trees and assuming that the following proportions of trees in the various classes survive to become Class I, *viz.* :—

85 per cent. of Class II,
70 per cent. of Class III,
40 per cent. of sound trees below Class III,

we can calculate the following results :—

85 per cent. of Class II will become Class I in 63 years.
82 per cent. of Class III will become Class II in 49 years.
57 per cent. below Class III will become Class III in 63 years.

Then, at the end of the 40 years' felling rotation we shall have the following amount of sound stock on the ground taking the average ages for classes as in the foregoing table :—

No.

Class I . $\left\{\frac{85}{100} \times 21{,}386 \times \frac{40}{63}\right\}$ . . . . . $=11{,}542$

" II . $\left\{\frac{\left(\frac{23}{63} \times 15\right) + 85}{100} \times 21{,}386 \times \frac{23}{63}\right\} \frac{82}{100} \times 43{,}125 \times \frac{40}{49}$ $=35{,}930$

" III . $\left\{\frac{\left(\frac{9}{49} \times 18\right) + 82}{100} \times 43{,}125 \times \frac{9}{49}\right\} \frac{57}{100} \times 552{,}698 \times \frac{40}{63}$ $=206{,}781$

Then, at the end of the 40 years' felling rotation we shall have the following comparing present Class I stock with what we shall have on the ground after the 40 years' felling rotation has been completed :—

Class.	Number of sound trees at present in stock as estimated from results of valuation survey.	Number of trees (calculated) which will exist after 40 years.
I	6,465	11,542
II	21,386	35,930
III	43,125	206,781
Under III	552,698	......

If anything, the stock thus calculated, which will exist after the 40 years felling rotation, is below the mark, as the above forecast is only for sound trees, and so the percentages taken in paragraph above should probably be larger.

The period over which the removal of the Class I sound teak and Classes I and II unsound teak might be distributed, was indicated by Mr. H. C. Hill to be the period it takes a Class II teak to become Class I, and this period has been found to be on an average 63 years. But as this period is supposed to be abnormally long, owing to past adverse conditions affecting growth in this forest, and as it is desirable to get all the large unsound trees out of the way as soon as possible, it was thought advisable to reduce this period to 40 years, especially as the calculation above given shows that the sound trees in Classes I and II will be nearly double the present sound stock at the end of the above period. It is probable however that two more preparatory periods of 40 years will be necessary before a normal growing stock is attained.

The distribution of the larger trees is very irregular, as can be seen from the detailed results of the valuation survey given in the Appendix E, so it is necessary for the compartments to be grouped together in five yearly sub-periodic blocks, so as to give an approximately regular yield. The order of the cuttings is given in the tabular statement of fellings.

Example III. All sound I Class trees *plus* trees of Class II that will never reach exploitable size.

A last example may be quoted, namely, that in which the removal is prescribed of such trees of the second and third class as it may be calculated will never reach exploitable size. Thus in the case of Mr. V. G. Morgan's working plan already quoted,* the following additional prescriptions occur :—

It is, however, also advisable to remove all the II Class trees which are unsound, mature or languishing during the same period. By examining the enumeration figures in Appendix IV of the working plan report, it would seem desirable to remove the 40 per cent. of which the majority are already considered to be mature and of which nearly 27 per cent. are already unsound.

This may safely be done as it leaves 11 trees per cent. more than the number in Class I estimated to be standing on the area, or 10 per cent. of the sound vigorous II Class trees remaining to allow for casualties, *i.e.*, windfalls, trees which dry up or for other reasons do not pass into the 6 feet girth class within the average period—among that class, while the remaining 90 per cent.—which is equivalent to 54 per cent. of the number of trees in Class II estimated to be standing on the area—are passing into Class I, and as the lower girth classes are well represented, unsound trees of Class III and lower girth which can be utilised will also be removed.

We thus have the number of trees which may be removed annually as :—

$$\frac{\text{I Class trees} + \cdot 4 \times \text{II Class trees} + \text{unsound III Class trees}}{30} \text{ or}$$

$$\frac{25{,}431 + 18{,}859 + 5{,}238}{30} = \frac{49{,}528}{30} = 1{,}650.$$

* Working Plan for the forests of the Motinala Range, Mandla Division, Central Provinces, by V. G. Morgan, I.F.S., *see* page 55 *ante*.

To regulate the annual yield in this way by number of trees alone is however not sufficient, and even dangerous, as it might not only lead to either over or under cutting these forests, but as it will also be necessary for sylvicultural reasons to retain a number of trees of exploitable girth.

The area to be dealt with annually is therefore laid down and except as stated below should not be exceeded. This area or annual coupe contains the maximum number of trees exploitable year by year, the number fluctuating in consideration of the different sylvicultural requirements of the several coupes.

It must therefore be distinctly understood that although the whole of the I Class trees should be removed as far as sylvicultural and economic considerations will allow, the total number of trees shown as available in the annual coupes is a maximum one, and is not to be worked up to if there are objections on the above score to the removal of any portion of the crop, or if the demand is lacking.

Under no circumstances is the total number of II Class trees shown in the tabular statement of fellings as available from year to year, to be exceeded.

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ii.—The Oudh Method.

If as in Brandis' Method the felling rotation be fixed at the number of years which it takes to replace the Class I trees, that is to say, the number of years required for the Class II trees to become Class I, it is evident that during that period, year by year, a certain number of Class II trees will pass into Class I, and consequently in addition to the number of trees of Class I which are present in the forest at the commencement of the felling rotation, it may be permissible to include in the possibility the number of trees which it is calculated will pass into Class I during that period: though it should be fully realized that in so doing, as already explained, the mean exploitable size will be reduced. The actual number of trees that can be so brought into the possibility will depend chiefly on the size of the annual coupes, that is, on the proportion of the whole forest worked over annually. If the whole of the forest is worked over annually, the whole of the second class trees (less a percentage that may fail to survive) will become of exploitable size and will be available for felling during the course of the felling rotation.* If on the other hand the forest is divided into a number of annual coupes corresponding to the number of years in the felling rotation, the maximum number of Class II trees, which will become available for exploitation in the coupes as they are worked over during that period will be equal to $\frac{1}{2}$ the Class II trees (less casualties). It is evident

* By felling rotation should be understood (as in Brandis' Method) the number of years required for a Class II tree of minimum dimension to become Class I.

therefore that under this method the possibility calculated for a period equal to the number of years which it takes a second class tree to become first class may be equal to the whole of the existing Class I trees *plus* the whole or a part of the Class II trees, the latter figures depending on the condition of the forest dealt with, and on the number of the annual coupes. Accordingly a study of existing working plans based on the Oudh Method will reveal a vast amount of difference as regards the proportion of Class II trees taken into the possibility.

Example I. All Class I trees *plus* $\frac{1}{10}$th of Class II trees.

The results of the enumerations given in detail in Appendix A of the Working Plan* for the Naini Tal Cantonment forests, United Provinces, show that—

We have a total of 2,381 trees of all species over $4\frac{1}{2}$ feet girth. These may all be removed during the next 20 years, should sylvicultural considerations admit of this.

Though we have no satisfactory data enabling us to fix the average rates of growth of the various species, it may be assumed that most of the trees take 40 years to pass from the second to first class, so that in addition to all trees of over $4\frac{1}{2}$ feet girth, one-half of those in the second class (which total 3,808) should theoretically enter into the possibility during the next 20 years, but there are several reasons why we cannot accept this in practice, the principal being--

(i) though it is probably fairly correct to say that a third class tree takes on the average 40 years to enter the second class, our data are unreliable and we must allow of a safety margin;
(ii) an allowance must also be made for deaths, windfalls, etc.;
(iii) the physical nature of the ground is often such as to render the removal of a tree inadvisable;
(iv) portions of the forest area are open to grazing; this demand may increase; at any rate it will probably not diminish and grazing cannot be entirely stopped.

Under these circumstances extreme caution is indicated in the removal of the existing stock of 2nd class trees, and it is therefore considered advisable to allow one-tenth of the stock of these trees to enter into the possibility during the next 20 years.

The annual possibility will thus be all trees of over $4\frac{1}{2}$ feet girth *plus* one-tenth of the existing stock of trees 3 feet to $4\frac{1}{2}$ feet girth divided by 20.

As the cantonment authorities have been accustomed to a volume outturn and understand it, the possibility is fixed in maunds of 100 lbs.

Using the factors given in para. 45 of the working plan report, and the result of the enumerations given in an Appendix, the total possibility for the next 20 years works out at 61,613 maunds, or an annual average outturn of $\frac{61,613}{20} = 3,080{\cdot}6$ maunds. It must be borne in mind that this is a maximum

* Working Plan for the Naini Tal Cantonment forests, Western Circle, United Provinces, by T. J. Campbell, I.F.S., 1904.

which it may be impossible to work up to owing to sylvicultural objections. Details of the calculation are given in the attached tabular form :—

Compartment.	Oak.			Miscellaneous.			Chir.			Total contents of Compartments in maunds.
	I.—Number of trees.	II.—$\frac{1}{10}$th of II. Number of trees.	Total contents in maunds.	I.—Number of trees.	II.—$\frac{1}{10}$th of II. Number of trees.	Total contents in maunds.	I.—Number of trees.	II.—$\frac{1}{10}$th of II. Number of trees.	Total contents in maunds.	
1 . .	85	9	2,261	40	5	678	1	...	40	2,979
2 . .	214	17	5,953	28	8	510	22	4	1,160	7,623
3 . .	133	10	3,694	31	7	544	18	19	1,100	5,338
4 . .	106	5	2,949	47	12	844	59	8	2,680	6,473
5 . .	215	7	5,753	269	34	4,398	7	1	300	10,421
6 . .	284	36	7,814	197	67	3,504	68	14	3,240	14,588
7 . .	128	12	3,308	38	10	684	30	5	1,500	5,492
8 . .	120	17	3,193	130	24	2,180	13	1	540	5,913
9 . .	40	16	1,024	8	1	132	6	4	360	1,516
10 . .	34	18	890	5	5	140	5	2	240	1,270
TOTAL .	1,359	147	36,839	793	173	13,614	229	58	11,160	61,613

REMARKS.

The factors taken in estimating the number of maunds available are :—

Species of tree.	Weight of fuel in maunds of 100 lbs. I	II
Oak . .	28	9
Miscellaneous	17	5
Chir . .	50	20

Example II. The whole of Class I trees *plus* $\frac{1}{5}$th of Class II trees.

In the case of the Bissau Working Circle of the Jubal State forests* containing Kail (*Pinus excelsa*)—

The enumeration showed that the following kail trees exist in the forests :–

Class I, over $2\frac{1}{2}$ feet in diameter	48,361
„ II, from 2 feet to $2\frac{1}{2}$ feet in diameter . .	59,699
„ III, from $1\frac{1}{2}$ to 2 feet in diameter . . .	84,844
„ IV, from 1 foot to $1\frac{1}{2}$ feet in diameter . .	100,572

The deficiency of trees of Class IV as compared with the number in Class III, is more marked than in the case of the deodar; on the other hand, the excess of over-mature trees is less than with the deodar, and it is believed that on the whole Classes V and VI are fairly represented. Moreover, the reproduction of kail is by no means bad and may be expected to become very good, as it almost invariably does in these hills when there is efficient protection of these

* Working Plan for the reserved forests of the Jubal State, Punjab, by E. M. Coventry, I.F.S., 1904.

forests. Finally, it must be remembered that kail usually occurs in places which are naturally favourable to its growth, and is not found in positions corresponding to that of deodar mixed with fir, when the inferior species is bound if left to itself to oust the more valuable one. Taking all these circumstances into consideration, it is clear that there is no need to exercise so much caution in fixing the yield of kail, as there was in the case of deodar. At the same time it is necessary to remember that large numbers of the kail will disappear in improvement fellings and thinnings from the forests where they are mixed with deodar, and therefore, for the sake of safety, fewer trees should be felled at first than the enumeration figures would seem to indicate. The period occupied by a tree of 2 feet in diameter to become $2\frac{1}{2}$ feet in diameter being 26 years, it is believed that during those 26 years it will not be safe to fell more than all the first class trees *plus* one-fifth of those in the second class. The annual yield will, therefore, be $\frac{48,361+(\frac{1}{5} \text{ of } 59,699)}{26}=2,318$.

Example III. All Class I trees *plus* $\frac{1}{4}$ of Class II trees.

Turning next to the working plans prepared for the forests of the Old Central Circle of the North-Western Provinces and Oudh, and to the one relating to the Kumaun Forest Division,* it will be found that a larger proportion, namely one-quarter of the trees of the second class, is brought into the possibility.

We have seen that the total contents of the three working circles are as follows, sound trees only being considered :—

	SÂL SOUND.		SEIN (TERMINALIA TOMENTOSA) SOUND.	
	1st class.	2nd class.	1st class.	2nd class.
1. Sarkhet	4,084	17,643	5,094	8,350
2. Nandhaur	25,565	83,250	15,847	28,709
3. Kalaunia	15,451	51,099	19,593	24,245
TOTAL .	45,100	151,992	40,534	61,304

During the next 36 years we may remove all the 45,000 1st class sâl and the 40,534 1st class sein : also a certain proportion of the 2nd class sâl trees; now these are, at present, three times as numerous as the 1st class trees; everywhere under the benefits derived from fire-protection, trees of the younger classes are springing up in vast numbers; and the yield in the future will be very much greater than it is now. It is considered that one-quarter of the 2nd class trees may be safely utilised during the ensuing 36 years. For many of these are already mature, and after taking this proportion there will, at the end of the period, still be standing in these working circles more than 100,000 1st class sâl trees, and therefore the surplus stock will be materially increased: and remembering also that in the forests of Class B, and in some of those of Class A, there is a large quantity of timber stored up for the future, the removal during the period of 36 years of $\frac{1}{4}$ of the 2nd class sâl trees is amply justified.

* Working Plan for the Kumaun Forest Division, Central Circle, North-Western Provinces and Oudh, by F. Beadon-Byrant, I.F.S., 1893-1912.

During this period of 36 years all the trees now 2nd class will become exploitable; and every year on the average $\frac{152,000}{36}$ or more than 4,000 trees will reach maturity; and theoretically the true annual possibility of the forest is one-thirty-sixth of all the 1st and the 2nd class trees. But as we cannot work over all the forest every year, working up to this would entail cutting trees which are immature and capable of improvement, in the annual coupes, and it is at present considered wiser to restrict the number of 2nd class trees which may be utilised to one-fourth of the present stock, storing up the remainder to the enrichment of the forest and the benefit of the next generation.

In the case of the sein, the 2nd class trees are only half as many again as the 1st class trees, and during the first period the existing 1st class trees will amply supply the demand.

The possibility is therefore calculated to be :—

Working Circle.	Sál.	Sein.
1. Sarkhet . .	$\frac{4,084 + \frac{17,643}{4}}{36}$ = 235 trees per annum.	$\frac{5,094}{36}$ = 141 trees per annum.
2. Nandhaur .	$\frac{25,565 + \frac{83,250}{4}}{36}$ = 1,288 trees per annum.	$\frac{15,847}{36}$ = 440 trees per annum.
3. Kalaunia . .	$\frac{15,451 + \frac{51,099}{4}}{36}$ = 784 trees per annum.	$\frac{19,593}{36}$ = 544 trees per annum.

A second example of a working plan drawn up on the same lines is that relating to the forests of the Inner Saraj Working Circle of the Kulu Division, Punjab.*

The following are the trees to be considered in the Inner Saraj Working Circle :—

First class over 2 feet in diameter.	Second class over $1\frac{1}{2}'$ and up to $2'$ in diameter.	Third class over $1'$ and up to $1\frac{1}{2}'$ in diameter.	Fourth class over $6''$ and up to $1'$ in diameter.	Fifth class $6''$ in diameter and below.
15,836	12,762	35,237	Not enumerated, but believed to be well represented as a rule.	

* Working Plan for the Kulu forests, Punjab, by C. P. Fisher, I.F.S., 1898.

From which it appears that the number of first class trees available for exploitation is large, as compared with the number of second class trees. On the other hand, the third class trees are extremely well represented, as those of the lower classes are believed to be.

Assuming that all the first class trees, 85 per cent. of the second class ones, and 65 per cent. of those of the third class, are able to survive till the end of the first period, an estimate which, if anything, errs on the side of safety, there should be on the ground just before the commencement of the second period :—

First class trees	15,836
Second class trees	10,847
Third class trees	22,904

of which almost all the second and third class trees will, respectively, have attained to the sizes of the first and second classes.

In view of these figures, and considering the present condition of the crop, and the results that may be expected from the proposed management, it is thought that it will be safe to remove all the first class trees, and one-fourth of those of the second class which are expected to survive to the end of the first period, during the first 30 years. This will give $\frac{15,836+2,712}{30}=\frac{18,548}{30}=618$, say 620 trees a year.

In making calculations of the capability it is, of course, necessary to consider the state of the younger age-classes, in order that, as far as can be foreseen, the yield of the second period shall not be less than that of the first. Concerning the younger age-classes fairly reliable information is available, and assuming (*a*) that the duration of the second period will be 30 years and (*b*) that, during it, it will be possible to fell one-half of the existing 22,904 third class trees, which are expected to be on the ground, just before its commencement, there will be for the second period of 30 years—

$$\frac{8,135+1,452}{30}=\frac{19,587}{30}=652 \text{ trees a year,}$$

which means that there should be a sustained yield for 60 years, a yield which moreover may reasonably be expected to be able to be increased after that time has elapsed.

In considering the above figures for the second period it must not be forgotten that, probably, only 85 per cent. of the 22,904 third class trees will attain to the first class, so that really more than half of the available number would be taken.

Example IV. All Class I trees *plus* $\frac{1}{3}$rd of the Class II trees.

In the next example to be considered a still larger proportion, namely, one-third of the Class II trees are brought into the possibility. Thus in the case of the Siran Range forests*—

The calculations given in paras. 24 and 25 of the Working Plan Report tend to show that the exploitable size for the chil may be safely fixed at 7′ 6″ in girth or 2′ 6″ in diameter, measured over the bark, corresponding to an age of 115 years, and that 32 years are required for a 2′ 0″ tree to become 2′ 6″. The number of trees over about 7′ 0″ girth which have passed maturity and have ceased to grow would suggest that possibly a lower felling size than 2′ 6″ may be suitable, but at present there

* Working Plan of the Siran Range forests, Hazara Division, North-Western Province, Punjab, by A. V. Monro, I.F.S., 1905.

are not sufficient data to decide this point, moreover increased success in fire-protection may lead to improvements in this direction. The girth can be reduced if found desirable when the prescribed revision in 16 years' time is carried out.

The number of fairly sound *chil* trees counted in the Chil Circle is as follows:—

I . .	28,413 over	2′ 6″	diameter.
II . .	67,147	2′ 0″ to 2′ 6″	"
III . .	134,804	1′ 6″ to 2′ 0″	"
IV . .	160,306	1′ 0″ to 1′ 6″	"

A considerable proportion of the lower classes have stopped growing and will never reach first class dimensions, while some of the third and fourth classes will be crowded out by the more vigorous growth of their neighbours. Again the success which may attend the fire-protective measures prescribed in this report is uncertain and the reproduction is not by any means assured. Under these circumstances and under instructions from the Inspector General of Forests, the annual capability has been fixed at the 1st class trees *plus* one-third of the 2nd class, or $\frac{28,483 + \frac{67,147}{3}}{32} = 1,587$ or, say 1,600 trees.

The figures at the beginning of this paragraph include all trees not actually dry, all green trees however branchy, damaged and irregularly grown, must be reckoned in the yield.

The number of years taken by a 2nd class chil tree to become 1st class has been ascertained to be 32, and it is proposed to prescribe the felling of this species for that period. During this time the fellings will pass over the Circle twice.

Example V. All Class I trees *plus* ½ Class II trees.

In the next place it may be interesting to study certain Working Plans for forests in which ½ of the Class II trees are to be exploited during the period of the felling rotation.

To cite the instance of the sâl forests of the Dehra Dun Division, United Provinces,* treated under the selection system—

The present condition of the stock of trees in this forest cannot be taken as a criterion of what sâl trees can grow to under improved conditions of protection and management. Our knowledge, too, of the girth corresponding to commercial maturity is as yet imperfect, so that it would be inadvisable to adopt at present a too rigid limit as to the size of maturity. A girth of over 6 feet may however with safety be taken as the maximum size to which sâl can be profitably grown, while it is probable that a considerable proportion of the stock may never attain this girth. Accordingly, it is broadly laid down that all sâl and sein trees of over 6 feet girth may be considered fit for removal, as mature, and in addition such second class trees as are unsound or show signs of deterioration.

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* Working Plan for the Naini Tal Cantonment forests, Western Circle, United Provinces, by R. C. Milward and H. Jackson, 1903.

The present stock of sàl and sein is estimated to be as follows :—

	Girth.	Trees.
Class I	Over 6 feet	5,814
„ II (*a*)	5 feet to 6 feet	13,372
„ II (*b*)	$4\frac{1}{2}$ „ to 5 „	14,363
„ III	3 „ to $4\frac{1}{2}$ „	74,510

It may be presumed that as the whole of II Class will probably become Class I in 30 years, Class II (*a*) will not take more than 24 years to become Class I, and probably not more than 20 years.

The stock in Class II (*a*) comprises 50 per cent. of stems which it is considered will never mature, while Class II (*b*) has also many unsound stems (estimated at one-sixth of the whole).

The maximum annual possibility has, therefore, been calculated as follows :—

$$\frac{\text{I}}{24} + \frac{\text{II}a}{2\times 24} + \frac{\text{II}a}{4\times 24} \quad \frac{\text{II}\ b}{6\times 24}$$

which comes to 760 trees.

Mature trees of species other than sâl or sein are not included in this figure.

Again, to instance the Sukna sâl forests of the Kurseong Division * :—

The possibility of the Terai felling series has been calculated on the assumption based on results of measurements recorded in the Appendix, that the average annual diametral increment of a second class tree is one-fifth of an inch a year; in other words that the smallest sized-trees of the second class, over 1 foot 6 inches to 2 feet diameter, will attain a diameter of 2 feet in 30 years. On these grounds it appears justifiable to cut all the existing first and half the existing second class trees in the next 30 years, and that the possibility works out to $\frac{7{,}234+\frac{54{,}950}{2}}{30} = 1{,}157$ or, say, 1,150 trees.

Proceeding on the same lines, the maximum limit will eventually be reached, that is, the case in which the whole of the II Class trees, which it is estimated will survive to pass into the first class, are also brought into the possibility.

Taking into consideration the selection forest as a whole in which the Class II trees are normally distributed, the number of Class II trees that will annually reach exploitable dimensions will be equal to the whole of the Class II trees (less casualties) divided by the

* Working Plan for the reserved forests in the Kurseong Division, Bengal, 1905, by C. C. Hatt.

number of years which it takes a second class tree to pass into the first class. Again, if the whole forest be divided into "x" equal annual coupes, the number of Class II trees annually becoming exploitable in each annual coupe will be—

$$= \frac{\dfrac{\text{All Class II trees}}{\text{Number of years it takes a Class II tree to become Class I}}}{x}$$

If "x" be made equal to the period of the felling rotation, that is, equal to the number of years it takes a Class II tree to become Class I, the number of trees annually becoming exploitable in each coupe will be—

$$= \frac{\dfrac{\text{All Class II trees}}{\text{(No. of years in felling rotation)}}}{\text{No. of years in felling rotation}}$$

It follows, therefore, theoretically that if each coupe be worked over in regular order year by year, the number of trees of the second class, which will have passed over into the first class, to be found in each coupe as it is worked over will be at the end of the growing season—

$1 \times \dfrac{\dfrac{\text{All Class II trees}}{\text{Felling rotation}}}{\text{Felling rotation}}$ trees in the coupe worked over in the 1st year.

$2\times$	do.	do.	do.	2nd ,,
$3\times$	do.	do.	do.	3rd ,,
	...	...	...	...

$\text{Felling rotation} \times \dfrac{\dfrac{\text{All Class II trees}}{\text{Felling rotation}}}{\text{Felling rotation}}$ trees in the coupe worked over in the last year of felling rotation.

This formula is generally applied to the forest as a whole, by fixing the maximum possibility, in all cases where the forest is worked over once in the period of the felling rotation, as all Class I trees *plus* ½ Class II trees (calculating for the middle of the growing season).

As a purely theoretical application of these principles, however, the method of calculating the possibility for the sâl forests of the

Buxa Division,* Eastern Bengal, may be taken into consideration. It will be seen that the method therein followed has the inconvenience of prescribing an unequal periodical yield.

The plains series of the Buxa forests.—This has been divided into 15 coupes which are to be worked in succession for exploitable sâl trees. The number of such trees marked in each coupe should include—

(*i*) the existing Class I trees, including wind-falls but excluding trees required as seed bearers, and

(*ii*) such of the existing Class II trees as attain the minimum exploitable size before the exploitation of the coupe.

Theoretically, the average diametral increment being assumed to be 0·2 inches, one-thirtieth of the Class II trees should attain the minimum exploitable size every year, and the total number of Class II trees over that size found in any coupe at the time of its exploitation should equal one-thirtieth of the number of existing Class II trees multiplied by the serial number of the coupe. But in practice it will probably be found that the numbers of Class II trees attaining the minimum exploitable size are less than the estimates obtained by such a calculation. For though the diametral increment assumed is very moderate, the diameters of the existing Class II trees do not vary evenly between 1 foot 6 inches and 2 feet, and the number of trees just over 1 foot 6 inches in diameter must be much greater than the number just under 2 feet in diameter. In these circumstances it is thought reasonable to estimate the yield as follows :—

It is assumed that in the first five years of the felling rotation (1905-06 to 1909-10) the number of Class II trees attaining the exploitable size will about blanace Class I trees which must be left for seed or become windfalls, and that the number of exploitable trees out in coupes 1 to 5 will therefore about equal the number of Class I trees they now contain, which is 15,020. Thus the average yearly yield of these coupes should be about $\frac{15,020}{5}$ or, say 3,000 exploitable trees.

For the next five years (1910-11 to 1914-15) during which coupes 6 to 10 will be worked, it is assumed that the number of exploitable trees available for felling will be the existing number of Class I trees, or	10,622
plus five-thirtieth of the existing number (70,654) of Class II trees in coupes 6 to 10, *i.e.*	11,755
TOTAL .	22,397
Deduct for seed bearers and wind-falls, at 25 per cent. say	5,397
Balance of exploitable trees available for cutting	17,000
Average yearly yield	3,400
Similarly for the last five years (1915-16 to 1919-20) of the felling rotation the yield has been estimated as follows :—	
Existing number of Class I trees	10,236
Ten-thirtieth of existing number of Class II trees	21,424
TOTAL .	31,660

* Working Plan for the reserved forests in the Buxa Division, Eastern Bengal, by C. C. Hatt, 1905.

Less about one-third allowed for casualties and seed bearers	10,660
Balance of exploitable trees available for cutting .	21,000
Average yearly yield	4,200

iii.—General Possibility Method.

By dividing the total number of trees existing in certain girth (or diameter) classes by the number of years represented by those girth classes, a *general* possibility is obtained. Theoretically, the calculation may be made for the whole period of the rotation, and it may include all the trees existing in all the girth classes. Or, the general possibility may be merely calculated for a period equal to the number of years covered by a certain sequence of the higher girth classes. In addition corrections are made for casualties; the extent of such corrections in each girth class depending on the kind of trees which it is proposed should count against the possibility. As a rule the *general possibility* is based on the number of trees which it is calculated will survive to reach exploitable dimensions. The method of procedure may best be explained by a few examples.

The disadvantages of a "General Possibility" are that the possibility has to be calculated for a long period, and in addition the exploitable age has to be determined, always a matter of great difficulty and uncertainty under the Selection System.

For the application of this method in its simplest form, the prescriptions of the working plan for the Minhla forests of the Tharrawaddy Division, Burma,* may be taken into consideration.

The only system on which the forest can at present be worked is that of "selection fellings."

Example 1. Possibility calculated for the whole period of rotation.

The actual growing stock in the working circle is as follows:—

	Trees.
Trees above $2\frac{1}{2}$ feet diameter	7,720
Trees from 2 feet to $2\frac{1}{2}$ feet diameter	10,440
Trees from $1\frac{1}{2}$ feet to 2 feet diameter	15,950
Trees from 1 foot to $1\frac{1}{2}$ feet diameter	27,390
Trees below 1 foot diameter, dominant . . .	36,570
Trees below 1 foot diameter, suppressed . . .	39,230
Present stock of plantation, roughly estimated at 40 per cent. of the original stock	284,000

* Working Plan for the Minhla forest, Tharrawaddy Division, Pegu Circle, Burma, by H. A. Hoghton, 1898.

The growing stock may be divided into the following classes :—

I Class trees having 24 inches diameter in *dry* forest.
I Class trees having 26 inches diameter in *moist* forest.
II Class trees between 18 inches and 24 inches diameter in dry forest.
II Class trees between 18 inches and 26 inches diameter in moist forest.
III Class trees between 12 inches and 18 inches diameter.
IV Class trees below 12 inches diameter.

About one-third of the teak-producing area in the working circle may be taken as covered with moist forest and two-thirds with dry forest. Of the 10,440 trees between 24 and 30 inches in diameter two-thirds or 6,960 may be taken as growing in dry and one-third or 3,480 in moist forest. Of these 3,480 trees, granted that one-third or 1,160 are between 24 and 26 inches in diameter, they will not therefore be I Class trees. The proportion of 1,160 to 18,160, the total number of trees above 24 inches in diameter, is about one-fifteenth, hence it may be taken for granted that only fourteen-fifteenths of the trees over 24 inches in diameter will be I Class trees.

The classified growing stock will then be as follows :—

I Class trees $= \frac{14}{15}$ of 18,160 = 16,950.
II " " = 15,950 + $\frac{1}{15}$ of 18,160 = 17,160.
III " " = 27,930.
IV " " = 147,000.

In the absence of any reliable data to go on, let it be granted that trees of the different classes will survive to reach the exploitable age in the following proportions, namely :—

95 per cent of the I Class.
85 per cent of the II Class.
70 per cent of the III Class.
40 per cent of the dominant trees below 1 foot diameter.
10 per cent of the suppressed trees below 1 foot diameter and stock in plantations.

The growing stock on which the estimate of the average annual yield must be based will then be as follows :—

	Trees.
I Class	16,100
II Class	14,600
III Class	19,550
IV Class	46,900

From the results of Pressler's gauge borings and countings of annual rings on stumps and logs it is estimated that on an average a teak tree takes—

70 years to attain a diameter of 12 inches;
40 years to increase from 12 to 18 inches;
55 years to increase from 18 to 24 inches in dry and 26 inches in moist forest;

that is, a tree attains the lowest limit of girth for girdling in 165 years. Allowing 10 years more for the tree to attain its maximum of utility, the average annual yield for the first two periods, or a total of 70 years, might be—

$$\frac{16{,}100 + 14{,}600 + 19{,}350}{70} = 522 \text{ trees,}$$

or estimating for the whole revolution of 175 years—

$$\frac{16{,}100 + 14{,}600 + 19{,}550 + 46{,}900}{175} = 555 \text{ trees.}$$

From these figures it is apparent that it will be safe to fix the sustained average annual yield, that is, the number of trees to be girdled annually in the Minhla working circle, at 500 trees.

The following table shows the plan of girdling:—

Name of block.	Number of compartment.	Area in acres.	Estimated number of teak trees in 1888. Above 24 inches in diameter.	18 to 24 inches in diameter.	12 to 18 inches in diameter.	Number of trees to be girdled during sub-period.
		1st Sub-period 1889 to 1895				
West Minhla block	1	588	34	12	34	
	2	784	...	...	...	
	3	531	8	4	15	
	4	463	...	...	5	
	5	642	43	41	112	
	6	587	195	203	207	
	7	684	370	371	497	
	8	730	132	162	540	
	9	689	332	344	365	
	10	678	394	748	996	
	11	430	223	237	617	
	12	548	108	105	162	
	13	401	128	242	326	
	14	321	78	14	86	
	15	559	40	90	274	
	16	570	41	77	210	
	17	552	121	158	505	
Karen area	18	550	5	10	5	
	19	1,700	348	228	832	
	20	1,376	17	32	82	
	21	509	...	2	...	
South Minhla	22	305	486	171	450	
	23	358	639	365	962	
Total		14,555	3,742	3,616	7,282	3,500

Name of block.	Number of compartment.	Area in acres.	ESTIMATED NUMBER OF TEAK TREES IN 1888. Above 24 inches in diameter.	18 to 24 inches in diameter.	12 to 18 inches in diameter.	Number of trees to be girdled during sub-period.
2nd Sub-period, 1896 to 1902.						
South Minhla	24	362	322	229	799	
	25	428	511	402	634	
	26	549	1,122	974	1,003	
	27	316	195	445	818	
	28	320	290	264	334	
	29	369	243	224	408	
	30	455	923	545	558	
Total		2,799	3,606	3,083	4,554	2,500
3rd Sub-period, 1903 to 1909.						
South Minhla	31	402	370	480	830	
	32	376	499	384	858	
	33	484	656	620	1,102	
	34	295	252	443	768	
	35	261	459	363	528	
	36	263	196	180	213	
	37	613	542	755	1,250	
North Minhla	38	498	607	421	729	
Total		3,192	3,581	3,651	6,278	3,500

Name of block.	Number of compartment.	Area in acres.	ESTIMATED NUMBER OF TEAK TREES IN 1888. Above 24 inches in diameter.	18 to 24 inches in diameter.	12 to 18 inches in diameter.	Number of trees to be girdled during sub-period.
			4th Sub-period, 1910 to 1916.			
North Minhla	39	391	472	634	604	
	40	538	528	709	1,381	
	41	509	432	586	1,390	
	42	611	451	678	568	
	43	413	851	671	568	
	44	678	1,234	828	1,290	
Total		3,140	3,968	4,106	5,801	3,500
			5th Sub-period, 1917 to 1923.			
North Minhla	45	488	877	526	806	
	46	544	1,071	317	634	
	47	528	698	323	534	
	48	638	616	347	1,190	
Total		2,198	3,262	1,513	3,164	3,500
			Summary.			
1st Sub-period		14,555	3,742	3,616	7,282	
2nd " "		2,799	3,606	3,083	4,554	
3rd " "		3,192	3,581	3,651	6,278	
4th " "		3,140	3,968	4,106	5,801	
5th " "		2,198	3,262	1,513	3,164	
GRAND TOTAL		25,884	18,159	15,969	27,079	17,500

The following table shows the present distribution of I and II Class trees over the sub-periodical areas :—

Sub-period.	Area in acres.	I Class.	II Class.
First	14,555	3,315	3,315
Second	2,799	3,198	2,825
Third	3,192	3,175	3,300
Fourth	3,140	3,518	3,690
Fifth	2,198	2,894	1,470
Total .	25,884	16,100	14,600

The following table shows the number of trees which will be available for girdling during the first period :—

Sub-period.	Years of girdling.	Mean year.	Number available.	Number to be girdled.
First . .	1889-1895	1892	$3,315\frac{4}{65}$ of 3,315=3,519	3,500
Second . .	1896-1902	1899	$3,198\frac{11}{65}$ of 2,825=3,676	3,500
Third . .	1903-1909	1906	$3,175\frac{18}{65}$ of 3,300=4,035	3,500
Fourth . .	1910-1916	1913	$3,518\frac{25}{65}$ of 3,690=4,937	3,500
Fifth . .	1917-1923	1920	$2,894\frac{32}{65}$ of 1,470=3,617	3,500
Total .	...	...	19,787	17,500

The annual yield being fixed at 500 trees and the sub-periodical girdling areas defined, under no circumstances may the total number of trees to be girdled in the sub-period be exceeded, nor must the girdling extend beyond the prescribed area even if the prescribed number of trees be not obtained within it.

Example 2. General possibility per 100 Class I trees.

The next example* shows the calculation of a general possibility for every 1,000 Class I trees. The working plan is in other respects interesting, in that it enters into a discussion as to the correct sylvicultural system, to be applied to a *Pinus longifolia*

* Working Plan for the Naini Tal Sub-Divisional forests, United Provinces, by N. Hearle, 1898.

forest, and in showing the method adopted in calculating the mean annual increment of trees of different girths.

In these Chir (*Pinus longifolia*) forests the object to be attained was (1) to increase the number of exploitable chir trees with long clean boles, the demand for chir timber equalling or perhaps exceeding the present supply; (2) to increase the density of the stock; (3) to work the forests more regularly so that the stock of mature trees may be concentrated as much as possible consistent with the maintenance of jardinage.

It is important to remember the sylvicultural requirements of this pine. M. Boppe well remarks: "When a high forest is stocked with species of heavy cover it is easy to keep trees of all ages growing together, for the shade of the taller ones does not interfere with the healthy growth of those standing below them. But in the case of trees of light cover it is impossible to maintain by this system anything but an extremely thin crop, for the young trees cannot live under the shade of the older ones. For such species, the regular system with the age classes grouped together is the only one that can be successfully employed." This system would also enormously facilitate fire-protection for regeneration could be confined to a small part only of the circle instead of being spread throughout the whole area as at present. Having in view, however, the small and inadequate stock of large chir and the fact that nearly all these forests are too remote to be utilised for the fuel supply, the system cannot be introduced at once without an unjustifiable sacrifice of material. We could, however, thanks to the fact that many of the blocks contain almost entirely young trees, prepare the way for its eventual adoption, if hereafter considered advisable, by keeping at present to the jardinage system but adopting a long period between such exploitation and by felling in each compartment as its turn for working arrives all trees 5 feet 3 inches in girth and over. This was the treatment advocated by the Conservator (Mr. Dansey) and myself. The Inspector General of Forests, however, whilst approving of the present treatment of the somewhat similar Ranikhet forests which will eventually regularise the whole stock, prefers for the Naini Tal forests the maintenance of the selection system with a felling rotation of 20 years. The trees to be removed are, so far as may be possible, to be marked in groups, thus leading the way to the application of the group jardinage system. This is therefore the treatment that has been adopted.

The chir working circles must obviously be worked with the main object of obtaining the largest quantity possible of timber. Other things being equal the larger the trees are when felled, provided they are still sound, the better; for the amount of waste in conversion diminishes in geometrical ratio as the diameter increases. But in each case a natural limit to exploitable size is imposed by the prevailing conditions of soil and climate.

In accordance with the orders of the Inspector General of Forests 20 chir trees growing under normal conditions were taken and their rate of growth and increase in their timber producing bole traced between the girths of 4 feet 6 inches and 6 feet 6 inches. In the following analysis these calculations are given for every three inches in girth.

Analysis of 20 chir boles to show the

Serial number of Chir tree.	CIRCUMFERENCE 4′—6″.		CIRCUMFERENCE 4′—9″.		CIRCUMFERENCE 5′.		CIRCUMFERENCE 5′—3″.		CIRCUMFERENCE 5′—6″.	
	Volume of bole.	Average annual increase in Volume.	Volume of bole.	Average annual increase in Volume.	Volume of bole.	Average annual increase in Volume.	Volume of bole.	Average annual increase in Volume.	Volume of bole.	Average annual increase in Volume
	c. ft.	c. ft.	c. ft.	c. ft.	c. ft.	c. ft.	c. ft.	c. ft.	c. ft.	c. ft.
1	42	·53	48	·56	54	·59	58	·59	64	·60
2	57	·51	69	·57	78	·60	88	·64	98	·66
3	44	·60	46	·59	52	·60	62	·65	69	·66
4	57	·95	70	1·06	73	·95	80	·91	87	·87
5	39	·80	44	·81	50	·87	57	·93	65	·95
6	46	·80	52	·81	59	·79	68	·79	77	·79
7	37	·79	42	·84	47	·90	52	·96	59	·98
8	57	·70	65	·74	74	·77	82	·79	92	·79
9	50	·48	57	·51	64	·55	71	·58	80	·62
10	53	·77	67	·92	77	1·01	84	1·06	91	1·00
11	50	·68	55	·70	66	·76	74	·78	83	·82
12	40	·50	46	·53	52	·57	59	·62	67	·66
13	42	·58	48	·63	54	·66	61	·69	69	·70
14	41	·64	47	·67	54	·71	61	·73	69	·77
15	43	·64	47	·66	56	·74	63	·78	69	·80
16	48	·69	54	·70	64	·75	73	·77	82	·80
17	47	·52	52	·54	58	·58	63	·60	69	·64
18	49	·51	54	·61	62	·66	68	·68	77	72
19	42	·72	47	·77	54	·84	61	·89	69	·93
20	50	·73	57	·79	64	·83	78	·88	80	·94
TOTAL .	934	13·14	1,067	14·01	1,212	14·73	1,363	15·32	1,516	15·71
Average .	47	·66	53	·70	60	·74	68	·77	76	·79

average annual increment in timber.

Circumference 5′—9″.		Circumference 6′.		Circumference 6′—3″.		Circumference 6′—6″.		Remarks.
Volume of bole.	Average annual increase in Volume.	Volume of bole.	Average annual increase in Volume.	Volume of bole.	Average annual increase in Volume.	Volume of bole.	Average annual increase in Volume.	
c. ft.	c. ft.	c. ft.	c. ft.	c. ft.	c. ft.	c. ft.	c. ft.	
69	·62	74	·63	80	·65	86	65	From these figures it will be safe to assume the volume of timber yielded by an average II Class tree to be 60 cubic feet and by a I Class tree 100 cubic feet.
109	·62	120	·69	...	...	...	...	
73	·66	85	·66	...	...	...	...	
96	·86	107	·84	...	...	...	...	
75	·99	85	·97	93	·97	106	·90	
83	·76	92	·73	...	...	...	...	
65	·98	75	·95	84	·91	94	·90	
103	·89	112	·78	124	·79	...	...	
89	·66	99	·68	110	71	121	·70	
99	1·17	109	1·23	117	1·27	126	1·31	
90	·85	...	...	...	...	...	...	
74	·68	...	...	...	...	...	...	
77	·75	86	·78	95	·81	105	·84	
77	·80	86	·83	95	·86	...	...	
77	·82	79	·86	94	·87	105	·92	
91	·83	...	...	...	...	.	...	
74	·66	...	...	...	...	...	...	
85	·74	...	...	...	...	...	...	
77	·97	...	...	...	...	...	...	
88	·98	...	...	...	...	...	...	
1,574	16·20	1,209	10·63	895	7·84	743	6·22	
79	·81	93	·81	99	·87	106	·89	

It will thus be seen that as far as those individual trees are concerned which reach such dimensions there is a gradual increase in the annual increment up to a girth of 6 feet and even often above that girth. On the other hand a large proportion of the trees never attain this girth. To determine the exact size at which the chir can be most profitably exploited is not therefore an easy problem. It lies somewhere between 5 and 6 feet. Ring-countings on 212 stumps including the 53 stumps counted by Mr. Fernandez (*vide* page 14 of his plan) give the following results :—

Average number of rings per inch of radius—

1st.	2nd.	3rd.	4th.	5th	6th.	7th.	8th.	9th.	10th.	11th.	12th.	13th.	14th.	15th.	16th.	17th.
8	9	9	10	11	12	15	16	18	20	20	21	21	25	29	29	34

By increasing the number by 10, to allow for the time it takes the seedling to reach a height of 4 feet 6 inches, at which height the standing trees are usually measured and allowing from 0·3 to 0·6 inches for the thickness of the bark, according to the size of the tree, we arrive at the following :—

Diameter	6 inches at breast height,	age	33	years	lowest IV Class.
,,	12	ditto	ditto	65	,,	III ,,
,,	17	ditto	ditto	105	,,	4′—6″ girth.
,,	18	ditto	ditto	112	,,	lowest II Class.
,,	19	ditto	ditto	125	,,	5′—0″ girth.
,,	20	ditto	ditto	135	,,	5′—3″ ,,
,,	24	ditto	ditto	169	,,	lowest I Class.
,,	30	ditto	ditto	242	,,	

Therefore it takes :—

33 years for the seedling to enter the IV Class.

32	ditto	lowest	IV Class tree to enter the		III Class.
47	ditto	,,	III	ditto	II ,,
57	ditto	,,	II	ditto	I ,,

Taking the percentages of trees passing from one class to the other as determined by my re-enumerations—

43 per cent.	of II	Class trees	become I	Class	within the average time.
56	do. III	ditto	II	ditto	ditto.
25	do. III	ditto	I	ditto	ditto.

The present proportion of the different classes being fairly normal and being in the proportion for every 1,000 trees as

I.	II.	III.
1	4	11

we find the general possibility for every 1,000 exploitable trees to be—

(1) If the exploitable girth be 6 feet—

$$\frac{(\cdot 43 \times 4{,}000) + (\cdot 25 \times 11{,}000)}{104} = 44 \text{ trees.}$$

(2) If the exploitable girth be 5 feet, it will be safe to suppose that 1,500 out of the 4,000 II Class trees are below that girth, and that 75 per cent. of them will eventually reach that girth in the average time. The average time it takes a III Class tree of the lowest dimensions to become 5 feet in girth is 60 years.

$$\frac{\cdot 75 \times 1{,}500 + \cdot 50 \times 11{,}000}{60} = 110 \text{ trees.}$$

It has been shown that a I Class tree contains about 100 cubic feet of timber and II Class tree 60 cubit feet.

The general possibility in cubic feet of timber for every 1,000 exploitable trees would be therefore—

		Cubic feet.
For an exploitable girth of	6 feet	44 × 100 = 4,400
Ditto	5 „	100 × 60 = 6,600

It would thus seem best to fell our trees as close as possible to a girth of 5 feet, but the smaller the tree the greater the loss in conversion and sawyers object to take trees below 5 feet 3 inches in girth. This we may, therefore, adopt as the exploitable age.

The above calculation is based on the supposition that the present proportion of the different classes, taking the forest as a whole, is fairly normal. The Inspector General of Forests (*vide* his remarks in the Appendix) does not consider this to be the case—a conclusion due, it is believed, to misconception (*vide* my letter No. 100 of 31st July 1897 in the same Appendix). However, he accepts for other reasons given in his remarks a girth of 5 feet 3 inches as approximating very closely to the correct exploitable size. The average age of chir trees of this size would be 135 years.

In accordance with the wishes of the Inspector General of Forests the length of the felling rotation adopted is 20 years. The exploitable size has been fixed at a girth of 5 feet 3 inches.

We may assume that half the present II Class trees are under 5 feet 3 inches in girth and from what has gone before that 65 per cent. of these will become exploitable within the average time, as well as 50 per cent. of the III Class trees. The proportion of the different classes is :—

I	1
II	4
III	11

and this is fairly normal as already explained. Therefore the general possibility for every 1,000 I Class trees would be—

$$\frac{\cdot 65 \times 2{,}000 \times \cdot 50 \times 11{,}000}{70} = 97 \text{ trees over } 5'\text{-}3'' \text{ girth}$$

There being at present in the—

	I Class trees.			
Ninglat Working Circle .	8,847	the general possibility	=	858
Manora ditto .	4,710	ditto	=	456
		TOTAL .		1,314

We must also take into account the present number of mature trees and divide these by 70. We have—

	Mature trees.	Can be felled yearly.
Ninglat Working Circle	28,147	402
Manora ditto	12,490	178

The possibility becomes therefore—

Ninglat Working Circle	1,260
Manora ditto	634

It is estimated, however, that not more than 75 per cent. of the chir will be found fit for timber, and as only such trees can be worked out the possibility should be reduced to—

		Estimated yield in firewood for Commissariat besides timber.
Ninglat Working Circle	950	34,200 maunds.
Manora ditto	450	16,200 „
TOTAL .	1,400	50,400 „

The Ninglat block which has only just been worked over has not been valued and is not to be regularly worked during the next 20 years. Any mature trees may, however, be removed if considered advisable.

This is for 20 years, or for one felling rotation from 1st July 1896 to 30th June 1916, at the end of which period the plan will have to be revised.

Example 5. Possibility calculated for periods of various length.

By way of comparing the results which may be obtained by calculating a general possibility for periods of different lengths in the case of forests which are not altogether in a normal condition the following extracts, taken from the Working Plan for the Trans-Sarda forests, United Provinces,* may be perused.

From the different enumerations between 1885-86 and 1894-95 the average stock of sâl per acre in 1902-03 is estimated to be :—

I.	II.	III.	IV.	V*a*.
2·82	6·90	10·04	18·7	30

Markings for fellings take place a year in advance of the fellings themselves; for this reason the calculations of stock are made for 1902-03 instead of for the year 1903-04.

* Working Plan for the Trans-Sarda forests, Kheri Division, United Provinces, by F. A. Leete, I.F.S., 1903.

In Appendix D of the working plan report details by compartments are given, and the method of calculation is explained.

The following remarks may be noted :—

(*a*) *Girth-percentages.*—It is assumed that the trees in each class pass up into the next higher class as follows, within the average periods given in paragraph 44 :—

Class.	Girth.	Percentage passing up.	Period.
I to M .	6′—0″ to 7′—6″	90	30 years.
II to I .	4′—6″ to 6′—0″	80	30 „
III to II .	3′—0″ to 4′—6″	75	25 „
IV to III .	1′—6″ to 3′—0″	60	30 „
V to IV .	0″ to 1′—6″	35	35 „

(*b*) There is good reason to suppose that the enumerations of 1891-92 and 1893-94 gave too large figures. The numbers of exploitable trees based on them as given in the working plans have not always been found.

Locality.	Year of enumeration.	TOTAL NUMBER OF TREES.		REMARKS.
		I.	II.	
Bhadi Working Circle.	1886-87	*143,749	180,178	* After deduction of trees felled between 1886-87 and 1891-92.
	1891-92	129,467	291,440	
Kanjaria Working Circle.	1886-87	56,786	119,094	
	1893-94	51,545	151,164	

The fairly close correspondence between the numbers in Class I and disparity between those for Class II are noticeable. For this reason, in the calculations of stock now made, the 1891-92 and 1893-94 figures for Class I and the 1886-87 figures for Class II have been adopted, and no allowance is made for growth in Class II in the interval between the enumerations.

The following table shows the stock of *sâl* per acre in compartments 27 and 33 in 1885-86, as calculated therefrom for 1902-03 and as actually enumerated in 1901-02, respectively—

——	I.	II.	III.	IV.	V*a*.
(1) Survey of 1885-86 .	1·88	4·25	9·3	37·1	105
(2) Calculated for 1902-03	3·60	6·45	15·2	51·0	?
(3) Actuals for 1901-02 .	2 06	6·10	15·6	49·8	210

All classes agree except the highest and lowest. (3) shows results slightly smaller for Class I than is actually the case as the callipers used were graduated to 6 inches diameter classes. Trees between 6 feet and 6 feet $3\frac{1}{2}$ inches are thus included in Class II, and so on.

(c) *Inclusion of all trees.*—The classification into sound and unsound trees varies so greatly in the different enumerations, and in the records of trees felled, that it is impossible to separate the one from the other. For the purpose of estimating the financial results of past and future working it would be of great value to know the proportions between sound and unsound trees. Although this cannot be ascertained now, there is some use in dealing with the figures for all trees, good, bad and indifferent, because they enable us to estimate what the total stock now is, and the changes in numbers which may be expected in the near future.

(d) Compartments 1, 2, 60, 71*a*, 72 to 75 are not included in the above calculations for Classes I and II as the trees to be felled in them in the course of the next two years have not yet been marked.

The *sâl* forests will be worked under the selection system with a felling rotation of 30 years. The annual coupes will be of approximately equal area. The exploitability for the *sâl* will remain at 6 feet during the first half of the rotation, but will be raised to 6 feet 9 inches in the second half of the rotation.

The possibility in I Class *sâl* trees is estimated to be 16,800 trees per annum for the felling rotation as a whole. As it is very unlikely that the first 15 coupes will be found to contain at the time of felling more than an average of 12,000 I Class *sâl* trees, it is decided, as a precautionary measure, to prescribe this figure as a *maximum*. The fellings of I Class *sâl* trees in any one year are therefore not to exceed a *maximum* of 12,000 trees. This limitation will also apply to coupes xvi and xxx.

The general working scheme is to remove by selection fellings during the next 30 years as much of the yield as can be done in view of the deficiency there is at present in all classes, and of the desirability of raising the standard of exploitability of *sâl* above 6 feet.

The possibility has been fixed by area with a limit to the total number of I Class *sâl* trees to the felled in any one year in the two working circles taken together.

The total stocked area of the east and west *sâl* working circles is 90,436 acres; so that the sum of the coupes averages 3,015 acres annually.

Details of the stock of *sâl* it is estimated that there will be when the plan comes into force, are given in Appendix D; and above the average per acre has been shown to be—

I.	II.	III.	IV.	V*a*.
2·82	6·90	10·04	18·7	30

Using the percentages and periods given above the possibility works out to be as follows for I Class *sâl* trees (exploitable at 6 feet) :—

(i) For 30 years—

= 2·82 + 40 per cent. of 6·90 per acre.

= 5·58 × 3,015.

= 16,824 trees ; say, 16,800.

(ii) For 55 years—

= 2·82 + 80 per cent. of 6·90 + 30 per cent. of 10·04 per acre.
= 11·35 per acre for 55 years.
= 6·19 do. 30 „
= 6·19 + 3,015.
= 18,663 trees; say, 18,600.

(iii) For 120 years—

= 2·82 + 80 per cent. of 6·90 + 60 per cent. of 10·04 + 36 per cent. of 18·7+12·6 per cent. of 30 per acre.
= 24·87 per acre for 120 years.
= 6·22 do. 30 „
= 6·22 × 3,015.
= 18,753 trees; say, 18,700.

As already stated, it is intended to restrict the fellings during the next 30 years to a maximum of 12,000 I Class *sâl* trees in any one year. The balance to be reserved is 28·6 per cent. of the full number available. This provides an ample margin for possible overestimation of the existing stock, and of its rate of growth.

The felling rotation is 30 years, for which period 30 annual coupes in each working circle are prescribed. Fifteen years hence (1917-18) the plan will be revised where necessary, in order to improve on the arrangement of coupes XVI to XXX.

Possibility calculated for equal periods.

The following example, though not strictly appertaining to the general possibility method, may here be quoted:—

The Thonze Reserve,* like all other mixed forests in British Burma, will have to be worked on the system of "Selection fellings." As already stated, the rotation has been fixed at 150 years, which has been divided into five periods of 30 years each, the latter being the length of time it takes an average second class tree to attain first class dimensions. The present growing stock in the workable parts of the reserve is estimated as follows:—

1st Class Teak trees 2 feet diameter and above . .	24,741
2nd Class Teak trees 1½ to 2 feet diameter . .	37,867
3rd Class Teak trees 1 to 1½ feet diameter . .	89,467
4th Class dominant teak trees below 1 foot diameter .	192,827

It is not likely that the whole of these will come to maturity, but as an approximation of the number of trees that will be available during the next 150 years the following may be taken:—

The whole of the first class trees	24,700
Four-fifths of the second class trees	30,300
Three-fifths of the third class trees	53,700
Two-fifths of the fourth class trees	77,100
TOTAL .	185,800

* Working Plan of the Thonze Reserve, Tharrawaddy Division, Pegu Circle, Burma, by J. W. Oliver, 1885.

or an average of 37,160 trees for each period, exclusive of trees in plantations, which may for the present be left out of account. At the rate of growth in dry forests as ascertained by borings, the diameter increase of trees during a period of 30 years is as follows :—

Second class trees	$0·144 \times 30 = 3·4$
Third class trees	$0·162 \times 30 = 4·9$
Fourth class trees	$0·244 \times 30 = 7·3$

and therefore

		30 years,	60 years,	90 years,	120 years,	150 years
		have a diameter of				
		Ins.	Ins.	Ins.	Ins.	Ins.
Trees with a present diameter of	20·6	24	...	...	...	...
	17·2	20·6	24	...	...	...
	12·3	17·2	20·6	24	...	...
	5·0	12·3	17·6	20·6	24	...
	1·0	8·3	15·6	17·6	22·9	26·3

so that, taking 6 feet girth as the marketable size, the whole of the second class trees and at least one-eighth of the third class trees will be fit to fell during the first two periods. In moist forest the diameter increase during 30 years is :—

For first class trees	$0·155 \times 30 = 4' \ 6''$
For second class trees	$0·174 \times 30 = 5' \ 2''$
For third class trees	$0·255 \times 30 = 7' \ 6''$
For fourth class trees	$0·241 \times 30 = 7' \ 2''$

And if 27 inches diameter (7 feet girth) be here taken as the minimum size for felling, a proportion of third class trees equal to that in dry forest will become available during the next 60 years. This gives a total number for the first two periods of—

all first class trees	24,700
all second class trees that will reach maturity . ,	30,300
one-eighth of similar trees in third class . .	6,700
Total .	61,700

Of these it is proposed to girdle during the first period—

all first class trees	24,740
all second class trees	5,260
Total .	30,000

or 1,000 per annum, leaving the balance of 31,700 for the second period. It is of course understood that it may not be convenient to remove all first class trees, as many may have to be left standing either on account of unsoundness or

because they are required for seed purposes: but the deficiency can be easily made good from the second class, many of which in the drier parts are even now 6 feet in girth (23 inches diameter) and consequently fit for felling. Of the trees estimated to reach maturity there remain—

seven-eighths third class	46,970
all fourth class	77,130
TOTAL, say .	124,000

which it is proposed to allot as follows:—

to third period, five-eighths 3rd class trees . .	33,600
to fourth period, two-eighths 3rd—4th class . .	44,200
to fifth period, three-fifths 4th class . . .	46,200
TOTAL .	124,000

This allotment is of course only a rough approximation and is only given to show that the younger classes are sufficiently well represented. The plantations should yield at least 12,000 first class trees, which will go to swell the outturn in the later period.

iv.—The Burma Method.

The Burma Method is based on the number of trees that annually reach the exploitable size during a given period. The size (girth or diameter breasthigh) of the exploitable tree and its age (rotation) having been determined, the possibility consists in ascertaining the number of trees which annually reach that size. This possibility may be determined either on the number of trees which may be supposed to reach the exploitable size during the whole period of the rotation, or during a shorter period of the rotation only. Again, in the latter case, this period may be made equal to the number of years that a tree remains in the penultimate* girth class, or merely a fraction of the whole rotation.

All trees above the exploitable size actually existing in the forest would naturally constitute surplus stock, and they may be removed within any suitable period of time in addition to the real yield, calculated as above explained on the annual increment of the forest, that is, on the number of trees annually attaining the exploitable girth.

* By penultimate girth class is meant the girth class immediately preceding the girth class which has been fixed for the minimum exploitable size.

If the trees below and up to the exploitable size be enumerated in suitable girth or diameter classes, and the number of years represented by each girth or diameter class be ascertained, the annual possibility for the first period will under the Burma method be—

$$= \frac{\text{The number of trees included in the penultimate girth class (less casualties)}}{\text{The number of years in that girth class}}$$

$$plus\ \frac{\text{Surplus stock}}{\text{A suitable number of years}}.$$

As a rule the surplus stock is removed in the number of years represented by the felling rotation. It is evident that the full possibility so calculated will only be applicable in the case where the whole of the forest is worked over annually. If only a portion of the forest be worked over annually the number of trees which will have attained the exploitable size in any one compartment will depend (as has already been shown in considering the Oudh Method) on the year in which that part of the forest comes to be worked over; and in order that the full possibility may be obtained from each portion of the forest as it comes to be worked over it is necessary that a stock of exploitable trees, varying in number according to the year in which the area is felled over, must always exist on the ground.

Thus,

Let x = number of trees in the oldest girth class that will survive to reach exploitable size.

Let n = number of years it takes a tree to pass through the penultimate girth class.

Then the number of trees annually becoming exploitable over the whole area will be $= \frac{x}{n}$ trees.

If the felling rotation be equal to r years; then the number of trees annually becoming exploitable in each coupe will be—

$$= \frac{\frac{x}{n}}{r}, \text{ or}$$

$$= \frac{\frac{x}{n}}{n}$$

If r be taken equal to n,

Consequently in order that $\frac{x}{n}$ trees may be felled annually, the stock of exploitable trees which must always be standing on the area will be—

$$n \times \frac{\frac{x}{n}}{n} = \frac{x}{n} \text{ trees in the first coupe worked over.}$$

$$(n-1) \times \frac{\frac{x}{n}}{n} \quad ,, \quad ,, \quad \text{2nd} \quad ,, \quad ,,$$

$$(n-2) \times \frac{\frac{x}{n}}{n} \quad ,, \quad ,, \quad \text{3rd} \quad ,, \quad ,,$$

$$2 \times \frac{\frac{x}{n}}{n} \text{ trees in the } (n-2) \text{ coupe worked over.}$$

$$1 \times \frac{\frac{x}{n}}{n} \quad ,, \quad ,, \quad (n-1) \quad ,, \quad ,,$$

$$0 \quad ,, \quad ,, \quad n\text{th} \quad ,, \quad ,,$$

$$= \left(\frac{x}{n} \times \frac{n}{2}\right) = \frac{x}{2} \text{ for the whole forest.}$$

The possibility so calculated may further be corrected according to the condition of the forest, that is according to the density of the stocking and to the number of trees found to be existing in the older girth classes. A few examples taken from existing working plans will explain the method of procedure under varying conditions.

Example I. The felling period = number of years passed in the penultimate girth class.

The following extracts are taken from the working plan of the Kabaung Reserve, Lower Burma*.

The object to be attained is to obtain as large a yield as can be extracted without infringing on the normal stock of the forest and which can be maintained equally from year to year.

---

* Working Plan of the Kabaung Reserve, Toungoo Division, Tenasserim Circle, Burma, by H. Carter, I.F.S., 1895.

In exploiting a forest of this description, that is, a forest in which one species alone, in this case teak, has a marketable value, but which is mixed with many other species, only one method is possible, namely, the selection method, which here will take the form of selection girdlings. These girdlings will be confined to certain areas and will be arranged so that the whole area is gone over in a reasonable time, those areas which are ripest for girdling being taken in hand first.

The rate of growth of the teak was determined by borings with Pressler's gauge and by counting the rings on stumps. Full details are given in Appendix III and a summary of the results here.

Size class.	Age of trees of lowest dimension of class.	Number of years required to pass into next class.	Age of trees of highest dimension of class.	REMARKS.
Up to 3 feet girth . . .	10*	63	73	*The number of years required by a seedling to establish itself.
3 to 4½ feet girth . . .	73	33	106	
4½ to 6 feet girth . . .	106	41	147	
6 to 7 feet girth . . .	147	30	177	

The counting of annual rings on stumps of trees below 3 feet girth gave 79 years as the age of a tree 3 feet in girth; the counting of rings on stumps of trees from 3 to 7 feet in girth gave 191 years as the age of a tree 7 feet in girth, while the two together gave 188 years as the age of a tree 7 feet in girth. If account is taken of the countings made on larger stumps, the age becomes 182 years. Comparing this with the results attained by the gauge, it will be seen that it would not be far wrong to take 180 years as the time required by a teak tree to attain a girth of 7 feet.

It has been shown in para. 11 that most of the area is covered with moist forest, and for practical purposes it may be taken as all moist forest. In this class of forest a girth of 7 feet has been fixed as the lowest girdling limit, as after attaining this size the trees are apt to decay and lose vitality, while trees below this size have a much smaller market value. The time taken to attain a girth of 7 feet may, therefore, be taken as the age of exploitability, and it has been shown in the preceding paragraph that this time is 180 years, which is therefore the age of exploitability.

This age of 180 years has been divided into 6 periods of 30 years each, during each of which girdling operations must extend over the whole area. A shorter period than this would be awkward from an administrative point of view and a longer period would leave mature trees standing too long. Moreover, 30 years is a very convenient period as it agrees with the time taken by a tree of the lowest dimensions of the II Class (6 to 7 feet girth) to attain to the lowest dimensions of the I Class. Each of these periods has been divided into five sub-periods of six years each.

As has been stated before, the general idea is to go over the whole area in 30 years, taking in hand first the areas which have most need of attention and extracting as much mature timber as a forest can yield without deterioration and without a subsequent diminution of the yield, steps being at the same time taken to increase the stock on such areas as may at present hold less than their

normal capacity; this obviously requires a determination of the possibility of the forest as it is at present.

According to para. 27 the number of sound teak of the first three classes now standing on the ground is—

I Class (7 feet and over)	67,973
II „ (6 to 7 feet)	38,092
III „ ($4\frac{1}{2}$ to 6 feet)	64,338

These will not all survive to be girdled, and we will assume that they will survive to be girdled in the following proportions :—

	Class.
95 per cent. of the	I
85 ditto	II
70 ditto	III

and we then get the following as the number of trees that will survive to be girdled :—

I Class	64 574
II „	32,378
III „	45,037

In paragraph 32 it was shown that it takes 30 years for a tree of the lowest dimensions of the II Class to attain to the lowest dimensions of the I Class. Therefore at the end of the first period (30 years) 64,574 + 32,378 = 96,952 trees would have become exploitable, or annually 3,232. The annual increment of the forest, which normally would be its annual yield, is the number of II Class trees which annually become exploitable, that is $\frac{32,378}{30} = 1,079$; and this shows that there is a large surplus on the ground. Moreover, it can be seen from the number of III Class trees, namely, 32,954, which pass into the II Class during the first period, that it is about the proper increment of the forest as at present constituted. As the whole area is not taken in hand at once but an area whose capacity is one-thirtieth of the total capacity of the forest, there must always be on the ground at the end of the period $\frac{30}{2} \times 1,079 =$ 16,185 exploitable trees. The surplus therefore will be 64,574—16,185 = 48,389 trees. If these were removed during the first period, there would be a great drop in the yield in the second period, and it is therefore proposed to spread their removal over about 2 periods (60 years) which would give 806 trees annually and a total annual yield 806 + 1,079 = 1,885 trees, or, in round numbers, it would be safest to say 1,800 trees.

This yield and the order in which the girdlings are to be made are only prescribed for a period of 30 years. At the end of this time the plan must be revised and the yield and girdlings altered and re-arranged if it is found necessary.

To estimate the condition of the crop at the end of this period we will assume that 50 per cent. of the IV and 25 per cent. of the V Class dominant will survive to be girdled, and we then see that the crop will be composed as follows :—

I Class	96,952—54,000 = 42.952.
II „	$\frac{30}{41}$ of 45,037 = 32,954
III „	12,083 + $\frac{30}{53}$ of 56,787 = 63.708.
IV „	5.162 + $\frac{30}{63}$ of 71.466 = 39,193.

It will be seen from this that there will be sufficient I and II Class trees to maintain the yield, while the number of III Class trees has greatly increased. The number of IV Class trees looks small, but it is impossible to say with any

approach to accuracy how many of the seedlings will arrive at maturity, and, if these are not included, the calculation of the number of V Class trees which pass into the IV Class is manifestly wrong.

As has been stated already, the whole area is to be girdled over in 30 years, which has been divided into five sub-periods of six years each. The area has been correspondingly divided into 5 sub-periodical areas, which have been equalised as much as was possible, having regard to proper distribution of trees during the sub-periods. The annual yield being 1,800 trees, the yield for each sub-period will be 10,800 and for the whole period 54,000.

Example 2. Felling period = a sub-multiple of the rotation (exploitable age).

As an example of a working plan prepared on the Burma Method in which the felling period is taken to be equal to a convenient sub-multiple of the whole rotation, the working plan for the East Yoma forests,* Burma, may be quoted.

The forest is mostly very uniform; there are patches of *indaing*, *ponzo* and jungle woods, but their area is unimportant and they are scattered through the teak forest. The Satsuwa and Tindaw reserves are in detached blocks, but they are small, so the three reserves will be included in one working circle.

The area has been divided into 51 compartments. The interior boundary lines follow natural features, streams, ridges, or spurs, and along these lines, except in the case of large streams, trees have been deeply blazed and marked with a C hammer. At all the intersecting or salient points hard wood posts have been erected bearing zinc numbers indicating the adjoining compartments and surrounded by a heap of stones or earth.

Main watershed ridges have been invariably selected as compartment boundaries, and within each drainage smaller watersheds and streams. The compartments were numbered by drainages, beginning in the east near the sources of each stream. The average size of the compartments in the East Yoma main reserve is 1,796 acres, in the Satsuwa and Tindaw reserves they are smaller as they contain many plantations, and the reserves are small.

The whole of the Tindaw reserve, Compartment No. 1, was counted out, as it is full of plantations and all the enumerators were available. In each of the other 50 compartments at least two sample plots were chosen.

The number of sample plots in the 50 compartments was 120, and their average area 195 acres: while the total area counted out in the whole working circle was 25,085 acres, being 29 per cent. Twenty recounts were carried out as a check on the work of the enumerators; some of the results were very good and most of the others fair.

In calculating the growing stock for the whole area 1,125 acres in Compartments, 45, 46, 48, and 49 have been subtracted from the area, representing precipitous unworkable slopes: 198·6 acres of streams must also be subtracted from the area statement: deducting these from 85,345·8 acres, the productive area is 84,022·2 acres. On this area the growing stock is as follows :—

Sound dead teak above 4½ feet in girth	10,485
Unsound teak above 3 feet in girth	18,642

* Working Plan for the East Yoma, Satsuwa and Tindaw Reserves in the Thayetmyo Division, Pegu Circle, Burma, by A. Rodger, I.F.S., 1906.

Unsound teak below 3 feet in girth	11,006
Sound teak above 7 feet girth	31,523
Sound teak 6 to 7 feet girth	18,114
Sound teak 4½ to 6 feet girth	42,768
Sound teak 3 to 4½ feet girth	101,737
Sound teak 1½ to 3 feet girth	150,910
Pyinkado above 7 feet girth	43,377
Pyinkado 3 to 7 feet girth	147,901
Cutch above 3 feet girth	3,832
Padauk above 3 feet girth	17,123
Myinma above 3 feet girth	931
Thingan above 3 feet girth	738
Kanyin above 3 feet girth	2,952
Ingyin and *thitya* above 3 feet girth	96,928
In above 3 feet girth	10,804
All others above 3 feet girth	906,152

The number of sound living trees above 3 feet in girth per 100 acres for the area of 84,022·2 acres is therefore :—

Teak	231
Pyinkado	228
Ingyin and *thitya*	115
Padauk	20
In	13
Cutch	5
Kanyin	4
Pyinma	1
Thingan	1
All others	1,078
TOTAL	1,696

The only large outturn from these forests during the first period will be teak timber, and the most important object therefore is to obtain the largest regular outturn of teak that the forest can yield without deterioration, while at the same time the value of the forest should gradually increase. The capital must not be encroached upon and the forest must be brought into a normal state. It is probable that a certain amount of cutch, *pyinkado* and *padauk* will also be extracted, but these will be dealt with separately.

In forests of this type containing a scattered growth of valuable species, among many others which at present have little or no value as they stand, the selection method must be adopted.

Teak timber sells best when of large size, the lowest limit for first class timber being ordinarily regarded as 6 feet girth.

Except in very dry forests, no teak is, as a rule, girdled unless it has attained a girth of 7 feet measured at breast height. In the forests under report there are a number of dry ridges on which teak, if it grows at all, will rarely remain sound until it has reached a girth of 7 feet, and will sometimes die before then. In such localities the exploitable size is 6 feet. These areas are mixed up with the teak forest proper and have not been separated in calculating the growing stock. No sharp line of division exists and the girdling officer must determine

whether teak trees should be girdled before they attain 7 feet in girth, or whether they may profitably be left until the next period.

The rate of growth of *pyinkado* is believed to be slower than that of teak, and a tree 7 feet in girth probably takes 200 years to reach it. Seven feet is the minimum girth at which *pyinkado* should be extracted. Cutch may be extracted at 4½ feet in girth as that size contains plenty of heartwood for boiling. Its rate of growth is about the same as that of *pyinkado*. *Padauk* grows probably at about the same rate as *pyinkado*. It should not be extracted below 7 feet in girth.

To determine the rate of growth of teak annual rings were counted on 198 logs and stumps. Large logs were available in some of the streams, and trees were felled of the middle and smaller classes for observation. The average radius was determined, and the rings counted on each inch of this radius, starting from the pitch. In this way data were obtained from each tree for every inch that it has increased in radius during its life. The totals for each inch were divided by the numbers of the trees counted and the following results were obtained :—

Inches radius.	Corresponding girth.		Average number of rings per inch radius	Number of years taken to reach each girth.
	Feet.	Inches.		
1	2	3	4	5
1	...	6	5	5
2	1	1	8	13
3	1	7	9	22
4	2	1	10	32
5	2	7	10	42
6	3	2	11	53
7	3	8	11	64
8	4	2	12	76
9	4	9	12	88
10	5	3	13	101
11	5	9	12	113
12	6	3	13	126
13	6	10	15	141
14	7	4	14	155
15	7	10	13	168
16	8	5	14	182
17	8	11	14	196
18	9	5	12	208
19	9	11	13	221
20	10	6	12	233

Allowing ten years for a seedling to establish itself the age of the average teak tree 7 feet in girth is therefore about 160 years. In the nearest adjoining reserves for which working plans have been made, this age has been fixed at—

	Years.
In the North Nawin reserve	150
In the Kabaung reserve	180
In the West Swa reserve	160

From the above table we find that the ages of teak trees at the limits of

the size classes are as follows in the East Yoma Working Circle, without adding on ten years :—

	Years.
$1\frac{1}{2}$ feet girth	21
3 feet girth	50
$4\frac{1}{2}$ feet girth	83
6 feet girth	120
7 feet girth	146

The rotation of 160 years will be divided into five periods of 32 years each, each of which will be divided into six sub-periods, four of five years each and two of six years each. The whole area will be worked over in each period, and the working plan must be revised at the end of the first period.

In paragraph 44 the number of sound teak standing in the forest is given as follows :—

	Trees.
Class I, above 7 feet girth	31,523
Class II, 6 to 7 feet girth	18,114
Class III, $4\frac{1}{2}$ to 6 feet girth	42,768
Class IV, 3 to $4\frac{1}{2}$ feet girth	101,737
Class V, $1\frac{1}{2}$ to 3 feet girth	150,910

It may be assumed that these trees will survive to be girdled in the following proportions :—

	Per cent.
Class I	95
Class II	85
Class III	70
Class IV	50
Class V	25

Giving the following numbers :—

	Trees.
Class I	29,947
Class II	15,397
Class III	29,938
Class IV	50,869
Class V	37,728

The first period lasts for 32 years. During it the following trees will be available for girdling :—

	Trees.
The whole of Class I	29,947
The whole of Class II	15,397
$\frac{6}{37}$ of Class III	4,855
TOTAL	50,199

because during the 32 years all the trees in Class II will pass from the lowest dimensions of Class II to the lowest dimensions of Class I, as they require only 26 years to do so (*vide* paragraph above).

To pass from Class III to Class II 37 years is required so, $\frac{6}{37}$ of Class III will grow through Class II into Class I, as the whole of Class II will have passed into Class I in 26 years.

The annual yield during the first period should therefore be $\frac{50,199}{32}$ or 1,569 trees.

There is, however, in the forest a large surplus. The annual yield being equal to the annual increment, in a normal forest all trees above 7 feet in girth would have been already removed and the yield for the first period would be the trees in the II and III Classes only, out of the total of 50,199, that is 20,252, giving an annual yield of 633 trees. The stock which should be always standing is half of the period increment or $16 \times 633 = 10,128$ trees. As there are 29,947 mature trees now standing which will be ready for girdling, the apparent surplus is 29,947—10,128 or 19,819 trees. If this surplus be removed during the first period the annual yield would be increased by 619 and would total 1,252 trees.

To modify this figure we have the following facts :—

(*a*) A certain number of trees are exploitable at 6 feet girth as they are growing on soil which cannot produce sound 7 feet trees.

(*b*) It is very desirable that a considerable number of large trees should be left, in order that the supply of large sized timber may not be exhausted, that sufficient trees may be left for natural regeneration, and that too many old trees may not be taken out of the forest until the results of the working of the first period have been seen. Working in this forest has taken place over such small areas that little idea of effects of concentrated and continuous felling can yet be had.

It is therefore proposed that the number of sound trees to be girdled annually be fixed at 1,000 trees.

In addition to these the yield will consist of sound dead timber and of unsound trees that can produce a marketable log. There are at present 10,485 sound dead any dry trees above 4½ feet girth in the forests and many of these will be extracted with girdled timber before they are destroyed by fire. There are also 18,642 unsound teak trees above 3 feet in girth of which a considerable proportion are above 5 feet in girth and can produce a marketable log and must be girdled : 5,000 such trees would increase the yield by 156 trees annually, and all such trees must of course be girdled before they deteriorate further.

The yield will be provided in the first instance by girdling teak trees, and the order in which this girdling is to be carried out during the first period must be prescribed. The yield for 32 years should be 32,000 sound teak, which will be girdled, and as there are 31,523 sound teak above 7 feet in girth now standing there should be no danger of the forest being overworked.

In prescribing the order of girdling the following points have been kept in view :—

(i) The present state of the growing stock, the number of sound teak above 3 feet in girth per 100 acres, and the number of unsound teak above 3 feet in girth, in each compartment.

(ii) The advisability of restricting the areas to be girdled in each sub-period to two or at the most three separate blocks of forests. This is necessary to facilitate control and extraction. It is advisable to have extraction going on in two or more drainages at once, in order that the contractors may not be all crowded together and that the streams may not become much blocked by falling trees, etc., as when left for many years unvisited they are very apt to be so. Contractors also prefer to have a certain drainage recognised as belonging to them and will sometimes work difficult forest in one valley rather than move a long distance to another.

(iii) The average number of trees above 7 feet in girth per compartment is 618. As some compartments contain between 1,500 and 2,000 such trees it is impossible to prescribe equal annual girdlings without making sub-compartments. The annual girdlings prescribed in the following table must therefore be abandoned if it is found necessary to girdle and extract equal numbers each year. The sub-periodical yield must, of course, be rigidly adhered to. It is quite possible that, owing to the variations in the number of logs that can be extracted from year to year, no objections will be found to this annual scheme.

Year.	Number of compartment.	Area in acres.	ESTIMATED NUMBER OF TREES ON THE GROUND IN 1905.			Number to be girdled.
			Above 7′.	6′ to 7′.	$4\frac{1}{2}$′ to 6′.	
1906-07	11, 12, 15	4.652	1,141	713	2,745	1,000
1907-08	17, 18	2.918	1,545	846	2,766	1,300
1908-09	24	1,885	96	643	1.347	850
1909-10	46. 51	3,538	1,346	775	1,381	1,150
1910-11	47	1,514	787	626	1,683	700
1st sub-period .	...	14.507	5,786	3,603	8,922	5,000
1911-12	19	1.768	1,623	837	1,601	1,400
1912-13	20	1,819	1,289	750	1,136	1,100
1913-14	23	1,489	843	393	735	800
1914-15	26	2,016	1,251	759	1,579	1,100
1915-16	25	1,975	656	377	714	600
2nd sub-period .	...	9,067	5,662	3,116	5,765	5,000
1916-17 . .	31. 32, 33	4,370	728	474	1,316	1,100
1917-18	34, 35	4.322	1,149	719	2.279	850
1918-19	36	1.979	871	449	1,464	1,350
1919-20 . . .	40, 41, 42	6,077	1.057	671	2,261	550
1920-21	43, 44	3,163	1,076	671	1.657	1,150
3rd sub-period .		19,911	4,881	2.984	8,977	5,000

Year.	Number of compartments.	Area in acres.	Estimated number of trees on the ground in 1905. Above 7′.	6′ to 7′.	4½′ to 6′.	Number to be girdled.
1921-22	45	2,489	968	622	1,139	1,100
1922-23	48	2,429	800	473	1,342	850
1923-24	49, 50	4,102	1,232	878	2,553	1,350
1924-25	16	1,913	514	401	730	550
1925-26	13, 14	3,151	1,018	639	1,587	1,150
4th sub-period	...	14,084	4,532	3,013	7,351	5,000
1926-27	1, 2, 3, 4, 5	6,457	764	723	1,958	900
1927-28	28	1,734	1,251	505	1,466	1,450
1928-29	27	1,307	531	249	568	550
1929-30	29	2,203	1,576	604	1,384	1,750
1930-31	21	1,206	311	254	477	350
1931-32	22	2,046	918	379	644	1,000
5th sub-period	...	14,953	5,351	2,714	6,497	6,000
1932-33	30	2,210	1,859	728	1,147	2,150
1933-34	38	1,734	464	225	608	500
1934-35	39	1,354	468	350	620	500
1935-36	6, 7, 8, 9	4,095	221	187	1,051	250
1936-37	10	1,092	300	201	478	350
1937-38	37	2,140	1,999	993	1,352	2,250
6th sub-period	..	12,625	5,311	2,684	5,256	6,000

= *Summary* =

Sub-period.	Area in acres.	ESTIMATED NUMBER OF TREES ON THE GROUND IN 1936.			Number of trees to be girdled.
		Above 7′.	6′ to 7′.	$4\frac{1}{2}$′ to 6′.	
1st sub-period . .	14.507	5,786	3.603	8,922	5,000
2nd „ „ . .	9,067	5,662	3.116	5.765	5,000
3rd „ „ . .	19,911	4,881	2.984	8,977	5,000
4th „ „ . .	14,084	4,532	3,013	7.351	5,000
5th „ „ . .	14,953	5,351	2,714	6,497	6,000
6th „ „ . .	12,625	5,311	2,684	5,256	6,000
TOTAL .	85,147	31,523	18,114	42,763	32,000

The following rules should be observed during girdling operations :—

(1) Except when it is necessary to retain them as seed bearers, unsound trees that will yield a log of marketable timber must be girdled. These trees do not form part of the annual yield of 1,000 sound trees and must be kept in a separate list.

Unsound trees may be considered to be those which contained a distinct cavity, near the ground or high up, or have their heartwood exposed to a height of at least 6 feet from the ground, and round at least half the diameter of the tree, or have had the top of the main stem broken off by wind.

(2) Except when it is necessary to retain them as seed bearers, the crowns of the trees being sufficiently free to bear seed, all trees attacked by *ficus* must be felled.

(3) Trees which have reached a girth of 6 feet and are growing in localities where it is evident that they will probably not reach a girth of 7 feet and remain sound must be girdled if they contain marketable timber and are not required as seed bearers.

Such trees occur principally in compartments 1 to 10, 13, 16, 20, 21 and 22, and the girdling officer will have no difficulty in deciding which are to be girdled.

(4) Isolated sound trees must never be girdled during the first period.

(5) Marketable trees, if quite sound and of good shape and growing close to the main streams, or in other localities where extraction is easiest, must not be girdled.

An estimate based on the figures in paragraphs 52, 53 and 54 of the larger sizes of the growing stock in 1938 is as follows :—

Class I, 50,199—32,000 = 18,199.

Class II, $\frac{26}{37}$ of 29,938 = 21,336.

Class III, $\frac{5}{37}$ of 29,938 + $\frac{32}{33}$ of 50,869 + $\frac{3}{29}$ of 37,728 = 57,277.

From Class II to Class I takes the first period of 32 years, less 6 years.
From Class III to Class II takes the first period of 32 years, *plus* 5 years.
From Class IV to Class III takes the first period of 32 years, *plus* 1 year.
From Class V to Class IV takes the first period of 32 years, less 3 years.

(*b*) *Pyinkado.*

Owing to the distance of the reserves from the river and the difficulty of extraction there is not likely to be any great demand for *pyinkado* from these forests during the next 32 years. The timber is valuable and it is possible that some may be worked out by purchasers, and converted on the spot either by steam saw-mills or hand labour.

Any demand that arises will be met by working the most easily accessible compartments: the stock in these alone will therefore be considered. *Pyinkado* was counted in two classes, 3 to 7 feet and above 7 feet. Subject to the working rules laid down below, any tree above 7 feet in girth may be felled. Of the total number of trees above 7 feet in girth a certain number are unsound or forked near the ground, and will not yield good timber. To make up for these, trees below 7 feet in girth which are unsound, those which should be removed because they are interfering with teak, and those which are growing on the poorest localities, may be felled. The number of trees above 7 feet in girth in the tables of growing stock may therefore be accepted as the yield for each compartment: these are given in the list below, for those compartments in which purchasers will probably be willing to work if any demand arises:—

Compartment No.	Number of *pyinkado* trees above 7′ in girth.	Compartment No.	Number of *pyinkado* trees above 7′ in girth.
		Brought forward.	6,274
1	121	29	1,384
4	138	30	1,101
5	214	36	1,077
11	220	37	1,657
12	363	43	409
17	695	44	561
18	564	46	573
20	946	47	738
23	833	49	859
24	1,029	50	528
28	1,101	51	621
Carried over .	6,274	Total .	15,732

If this be regarded as the total yield for the period the annual yield is 492 trees.

As it is at present impossible to estimate the extent and nature of the probable demand, it is unnecessary to lay down annual felling areas or the order in which they should be worked. The wishes of the purchaser should be consulted. The total stock of trees above 7 feet in girth is 43,377, so that there is no likelihood that *pyinkado* will be worked out. All dead timber should be worked out with the green timber marked, and one compartment should be thoroughly worked out before a new one is begun.

Trees for felling should always be selected by an experienced officer, who should observe the following rules :—

(i) The minimum girth for felling is 7 feet at breast height and no trees should be marked below that girth except as provided below.

(ii) No isolated tree must be marked unless there are young teak, *padauk* or *pyinkado* trees in the immediate neighbourhood.

(iii) Unsound trees, and those growing on the poorest localities, may be marked below 7 feet in girth, if they will yield marketable timber, and if they are not required as seed bearers.

Example 3. Possibility calculated for the whole period of the rotation.

In the following example* the possibility is calculated on the number of trees which it is estimated will annually reach exploitable dimensions during the whole period of the rotation, the removal of the excess trees being distributed throughout the rotation. The Deoban forest is a mixed silver fir, spruce, oak, deodar, and *Pinus excelsa* forest; and the possibility in the case of the firs is calculated as follows:—

The following statement shows the exploitable size and age of the fir trees, as well as the number of years they are supposed to remain in each class :—

Seedling stage. Number of years to reach 5′ in height.	V.—Number of years to grow from 5′ high to 6″ diameter.	IV.—Number of years to grow from 6″ to 12″ diameter.	III.—Number of years to grow from 12″ to 18″ diameter.	II.—Number of years to grow from 18″ to 24″ diameter.	Total age of trees of exploitable size.	Exploitable size
20	22	22	26	30	120	24″

The felling cycle has been fixed at 40 years; and the following are the estimated figures of the percentage of trees which pass from one class to another :—

95 per cent. Class I survive for 40 years.

80 per cent. Class II become Class I.

75 per cent. Class III become Class II.

60 per cent. Class IV become Class III.

$33\frac{1}{3}$ per cent. Class V become Class IV.

* Working Plan for the Government forests in Jaunsar-Bawar, United Provinces, (Deoban Working Circle), by P. H. Clutterbuck, I.F.S., 1901.

Taking these as given, the following are calculated from them :—

60 per cent. Class III become I.
36 per cent. Class IV become I.
12 per cent. Class V become I.
45 per cent. Class IV become II.
20 per cent. Class V become III.
15 per cent. Class V become II.

The following statement gives the stock of firs calculated for 1900 :—

Species.	I	II	III	IV	V
Firs	31,198	33,837	63,225	1,18,630	?

Taking the percentages given above, the annual possibility is calculated for the whole rotation of 120 years, the excess trees in Class I being distributed throughout the rotation, the average annual yield being—

$$\frac{(31198 \times \frac{95}{100}) + (33837 \times \frac{80}{100}) + (63225 \times \frac{60}{100}) + (118630 \times \frac{36}{100})}{(120 \times \frac{40}{2})^{*}}$$

$$= \frac{29698 + 2707[illegible] + 37935 + 4270}{140}$$

= 981 trees.

Taking the average annual yield of firs for the whole rotation of 120 years at 981 trees per annum, there ought to be $981 \times \frac{40}{2} \times \frac{100}{97 \cdot 5} = 20{,}123$ trees now in Class I, but there are 31,198 or an excess of 11,075.

And the following statement shows the number actually prescribed to be exploited annually :—

Species.	A. A. Y. for the whole rotation. Number of trees.	Excess or deficit stock in exploitable class.	Annual fellings prescribed.
Firs	981	11,075	800

Example 4. Surplus stock at commencement is inadequate.

Lastly in exceptional cases it may happen at the commencement of the first period of systematic working that the surplus stock which should be standing on the ground is insufficient or wanting. The procedure then to be followed may either be that of

* As the felling cycle is 40 years, there should always be on the ground $\frac{40}{2} \times$ (average annual yield) Class I trees; therefore $\frac{40}{2}$ must be added to the rotation for the denominator.

prescribing unequal sub-periodic returns (see Working Plan for the reserved forests in the Buxa Division, Bengal, page 348 *ante*); or better still the reserve stock may gradually be built up in the manner explained below:—

*Nagkelu Kail working circle.**—The number of blue pine trees in this forest is as follows:—

Class M—Over 2 feet diameter	908
Class I—$1\frac{1}{2}$ to 2 feet diameter	3,107

Also a tree increases from $1\frac{1}{2}$ feet to 2 feet diameter in 18 years. Supposing that only 90 per cent. of Class I reach exploitable dimensions, then every year on an average $\frac{3,107 \times \cdot 9}{18} = 155$ trees become exploitable, and, with a felling rotation of 18 years, the normal exploitable stock on the ground is—

$$\frac{155}{18} \times 18 \times \frac{19}{2} = 1,472.$$

There is thus a deficit of $1,472 - 908 = 564$ trees. Hence for the present only $155 - \frac{564}{18} = 124$ trees can be felled. The crop in this forest is complete, as the lower classes are abundant, so that it is considered quite safe to fix the yield at 100 trees per annum.

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v.—The Crown Cover Method.

The possibility under this method is taken to be equal to the growing stock which would be found standing on the oldest age gradation if the selection forest in question were worked on the method of clearances and with the same rotation. In other words, the number of trees which become exploitable every year under the selection system should be equal to the number which would be obtained from the same forest worked on the method of clearances with the same rotation.

The minimum girth or diameter of the exploitable tree being known, and the number of years (*i.e.*, rotation) required to produce a tree of that size, the possibility may be fixed as follows:—

Let A = the wooded productive area of the selection forest.

Let r = rotation or exploitable age.

Let a = the area covered by the crown of an average tree of the exploitable girth.

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* Revised Working Plan for the reserved forests of the Kotkhai and Kotguru Ilaquas, Simla District, Punjab, by E. M. Coventry, I.F.S., 1903.

Then the area occupied by each age gradation in a normal regular forest would be $= \frac{A}{a}$ acres. And the number of exploitable trees standing on the oldest age gradation would be $\frac{A}{r \times a}$: this representing the number of trees, which may be felled annually.

This method is based on certain hypotheses which may vitiate the accuracy of the results obtained. In the first place, it is by no means an accepted fact that the exploitable trees in a selection forest occupy the same area that they would in a regular forest.* In the second place, the possibility is based on a determination of the exploitable age, a calculation which does not always yield positive results in a selection forest. Thirdly, it necessitates the calculation of the crown cover of the exploitable tree, which is an operation requiring great care: though probably fairly satisfactory results might be obtained by the direct observation and measurement of small groups of exploitable trees.

To take a concrete example. Suppose the area of the forest be 1,400 acres; and the exploitable age required to produce a tree 6 feet in girth 140 years. The area which should be occupied by the trees 140 years in age, if these were collected together in one place, would be 10 acres. If now it is found that the average tree with a girth of 6 feet occupies an area of 600 square feet, the number of trees of the exploitable size that can grow on 10 acres, that is the number which may be felled annually, will be—

$$\frac{435,600}{600} = 726 \text{ trees,}$$

or ·5 tree per acre per annum.

It does not appear that this method has ever been applied in practice either in Europe or in India.†

vi.—*Possibility based on the Normal Forest.*

This method will be found fully described in the third volume of G. Huffel's Economie Forestière‡ from which the following extracts are taken. It will be best understood by giving an example from a working plan prepared in 1906 for the Rein des Boules Working Circle of the Ban d'Etival State forest situated in the Vosges, France. The forest is a mixed Pine and Beech forest.

* *See* Part I of this Note.

† *See* also Preparation of Forest Working Plans in India by W. E. D'Arcy. 3rd Edition, pages 88-89.

‡ Economie Forestière, by G. Huffel, Volume III, Lucien Laveur, Editeur, Paris, 1907.

From a study of previous enumeration surveys carried out in pine forests, it has been found possible to draw up a table laying down temporarily what should be the constitution of the various diameter classes in a normal selection forest. The following table shows the conclusions arrived at in the case of the Rein des Boules working circle:—

Diameter breasthigh.	Number of trees per hectare.	Volume of each tree.	Volume per hectare.
Centimeters.		Cub. meter.	Cub. meter.
15	126	0·1	12·6
20	90	0·3	27·0
25	60	0·5	30·0
30	43	0·7	30·1
35	30	1·1	33·0
40	22	1·5	33·0
45	17	2·0	34·0
50	13	2·5	32·5
55	9	3·1	27·9
60	7	3·7	25·9
65	5·5	4·4	24·2
70	4	5·2	20·8
75	3	6·0	18·0
80	2	6·9	13·8
85	1·5	7·8	11·7
90	1	8·8	8·8
95	0·5	9·9	4·9
Totals	434·5	...	388·2

Accepting this as a fairly correct representation of the normal forest, it follows that during the period of the felling rotation which has been fixed at 10 years, the number of trees removed must be replaced by an equal number of trees, which will have passed up from the lower diameter classes. If the higher diameter classes are too fully stocked, the surplus stock must be gradually removed;

whilst if the stocking is below the normal, the possibility must be proportionately reduced.

Suppose the size of the exploitable tree be taken as one with a diameter of 45 centimeters, it will be necessary to calculate by comparing the enumerations of 1885 with those of 1905 the number of trees with a girth below 45 centimeters, which may be expected to reach exploitable dimensions during the next 10 years. This may be worked out as follows:—

				Pines.	Beech.
In 1905, the stock consisted of		2,984	trees 45 cent. in girth	2,382	602
During the previous 20 years, the fellings have yielded	Between 1885 and 1896 . .	373	ditto	327	46
	Between 1897 and 1905 . .	505	ditto	394	111
	Total .	3,862		3,103	759
In 1885, the stock consisted of		2,684	ditto	2,480	204
Therefore number of trees which have passed into the diameter class 0·45 and over between 1885 and 1895		=1,178	ditto	623	555
Or annually		58	ditto	31	27

These 31 pine trees and 27 beech trees have been obtained yearly, from the 40 centimeter diameter class, and the average number of trees which stood in this class during the period of 20 years may be estimated as follows:—

In 1885, there existed 771 trees, 429 pines — 342 beech trees.
In 1896, „ 1,004 „ 392 „ — 612 „

Therefore average number of pine trees, 0·40m. in diameter $\left\{\dfrac{429 \times 11 + 392 \times 9}{20}\right\} = 412.$

Average number of beech trees, 0·40m. in diameter $\left\{\dfrac{342 \times 11 + 612 \times 9}{20}\right\} = 463.$

That is, 412 pines of the 40 centimeter diameter class have yielded, yearly, 31 pine trees of exploitable dimension or 7·5 per cent.;

and 463 beech trees of the 40 centimeter diameter class have given, annually, 27 beech trees of exploitable size, or 5·8 per cent.

Similarly, the percentage of trees belonging to the 45, 50, 55, 60, etc., centimeter diameter classes, which have passed into the class immediately above, may be calculated; and results so obtained are classified in the following table:—

Diameter.	Percentage passing into the next higher class.		Average percentage.
	Pine.	Beech.	
Cent.	%	%	%
40	7·5	5·8	6·6
45	7·5	5·9	6·7
50	8·5	6·9	7·7
55	8·1	7·7	7·9
60	8·9	7·6	8·2
65	9·2	7·6	9·2
70	9·6	7·6	9·6
75	9·9	7·6	9·9
80	10·0	7·6	10·0
85	11·6	7·6	11·6
90	12·0	7·6	12·0
95	20·0	7·6	20·0

To be on the safe side, the mean may be taken at the lowest figure above obtained, namely, that corresponding to a diameter of 40 centimeters. From which it follows that $\frac{2}{3}$ of the trees with a diameter of 40 and over will pass into the next higher diameter class during a period of 10 years. In other words, that a period of 15 years will be required for all the trees of one diameter class to pass into the next higher class.

Therefore, during the 15 years, it would be justifiable to fell the following number of exploitable trees, *viz.*:—

22 — 17 = 5	trees with a diameter of	45	centimeters.
17 — 13 = 4	ditto	50	„
13 — 9 = 4	ditto	55	„
9 — 7 = 2	ditto	60	„
7 — 5·5 = 1·5	ditto	65	„
5·5 — 4 = 1	ditto	70	„

4 — 3 = 1	tree with a diameter of	75	centimeters.
3 — 2 = 1	ditto	80	„
2·5 — 1·5 = 1	ditto	85	„
1·5 — 1 = 0·5	ditto	90	„
1 — 0·5 = 0·5	ditto	95	„
0·5 — 0 = 0·5	ditto	100	„

22 trees per hectare.

$$\text{Or in 10 years : } \frac{22 \times 2}{3} = 14{\cdot}6 \text{ trees.}$$

It will now be possible to calculate the possibility of each coupe. The Rein des Boules forest should when normally constituted contain 63·5 trees per hectare, with diameter of 45 centimeters and over; or 2,352 trees for the whole area of 37·04 hectares. The enumeration carried out in 1905 shows that there are actually 2,984 trees. In other words, that there exists a surplus stock of 632 trees, which must be removed. But, in order to proceed with caution, it will be safest (bearing in mind that the figures of the normal forest are purely hypothetical) to spread the removal of this surplus stock over 40 years; that is to say, during the first felling period of 10 years only $\frac{1}{4}$ of the available surplus stock will be removed.

Accordingly, the possibility per coupe may be calculated as follows:—

Number of	Area.	Normal possibility.	Trees with diameter 0·45 m. and over. Number which should be found in normal forest.	Actuals.	Difference.	One-quarter of the difference.	Total possibility.
	Hectares.	Trees.	Trees.	Trees.	Trees.	Trees.	
1	3·50	51	222	270	48	12	63
2	3·67	53	233	259	26	7	60
3	3·67	54	233	257	24	6	60
4	3·57	52	227	287	60	15	67
5	3·71	54	236	265	29	8	62
6	3·61	53	229	284	55	14	67
7	3·32	48	211	236	25	7	55
8	4·07	49	258	347	89	22	81
9	3·96	58	252	412	160	40	98
10	3·96	58	251	367	116	29	87
Totals	37·04	540	2,352	2,984	632	160	700

From which the following tabular statement of fellings to be made is obtained:—

Year.	Coupes.		Number of trees 0·45 m. diameter and over to be felled in each coupe.	REMARKS.
	Number.	Area.		
		Hectares.		
1906 . .	1	3·5	63	In compartments 2, 3, 4, 5, and 6 the possibility should be taken chiefly in beech trees. Dead trees over 45 cent. in diameter removed at any time from a compartment will count against the possibility when that coupe comes to be worked over. Following on the selection felling an improvement felling will be carried out. This may consist of thinnings, cleanings, and weedings. Thinnings should however be extremely light.
1907 . .	2	3·67	60	
1908 . .	3	3·67	60	
1909 . .	4	3·57	67	
1910 . .	5	3·71	62	
1911 . .	6	3·61	67	
1912 . .	7	3·32	55	
1913 . .	8	4·07	81	
1914 . .	9	3·96	98	
1915 . .	10	3·96	87	
Total .	...	37·04	...	

SECTION 3.—POSSIBILITY BY VOLUME.

When an absolutely equal annual sustained yield is a desideratum; in places where all the species of a mixed crop, as well as all sizes of trees, are saleable; and where the forest to be taken in hand is in a more or less normal selection condition, a possibility by volume becomes obligatory. Unfortunately such a state of affairs is at present seldom found to exist in an Indian forest. There, an absolutely equal annual outturn from year to year is frequently a matter of small importance; and what is more the trained establishment, which would be required to carry out exact enumerations and measurements of the whole standing crop periodically, and subsequently to carefully supervise the annual fellings, is not always available. Taking these facts into consideration, it will usually be

found that a possibility by number of trees will under existing conditions in India more nearly meet all present requirements. It will only be necessary therefore to briefly indicate the various volumetric methods of calculating the possibility, which may from time to time find an application in India. These various methods may be classified as follows:—

(i) Masson's or Von Mantel's Method.
(ii) The French Method.
(iii) Fellings limited by proportionate volume.
(iv) Gurnaud's Method.

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i.—Masson's or Von Mantel's Method.

The possibility under Masson's Method is calculated by the use of the following formula:—

$$\text{Annual yield} = \frac{\text{Real growing stock of the forest}}{\text{Half the number of years in the rotation}}.$$

This formula is based upon the idea that the real yield must bear the same proportion to the real growing stock as that existing between the normal yield and the normal growing stock.* That is—

Real yield : Real growing stock :: Normal yield : Normal growing stock.

$$\therefore \text{Real yield} = \text{Real Growing Stock} \times \frac{\text{Normal Yield}}{\text{Normal Growing Stock}}.$$

$$\text{But Normal Growing Stock} = \text{Normal Yield} \times \frac{\text{rotation}}{2}$$

$$\therefore \text{Real Yield} = \text{Real Growing Stock} \times \frac{\text{Normal Yield}}{\frac{\text{Normal Yield} \times \text{rotation}}{2}} = \frac{\text{Real Growing Stock}}{\frac{\text{rotation}}{2}}$$

This method was applied in calculating the yield for the Naini Tal Municipal forests, and from that working plan† the following extracts are taken:—

The forests form a convenient working circle of 1,640 acres.

The area dealt with has been divided into 27 compartments. In forming these compartments natural features have been taken as boundaries, and the composition of the forest growth has been considered.

The compartments have been examined and described in detail. Two types of forest lands have been recognised: *class A* (coloured blue on the map), consisting of well or fairly well stocked forest, in which trees of all ages are present,

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* See Schlich's Manual of Forestry, Vol. III, pages 320 and 323.

† Working Plan of the Naini Tal Municipal forests, Naini Tal Division, United Provinces, by F. B. Bryant, I.F.S., 1895.

and in which fellings may be undertaken; *class B* (coloured pink on the map), consisting of either very poorly stocked, precipitous slopes or of well stocked areas, in which, owing to danger of landslips or for the sake of the picturesqueness of the settlement, no fellings should be undertaken.

The following statement shows the result of this examination and classification :—

CLASS A.		CLASS B.	
Compartment No.	Area.	Compartment No.	Area.
	Acres.		Acres.
2 (part)	13	1	94
4	100	...	...
5	32	2 (part)	72
6	31	3	111
7	70	10	20
8	52	15	105
9	71	16	133
11	80	17	105
12	41	19AB	5
13	42	20	34
14	50	24 (part)	26
18	19	25	74
20	35	26	69
21	37	27AB	31
22	29	...	...
23	39	...	...
24 (part)	21	...	...
Total .	761	...	879

Further all stems over six inches in diameter have been enumerated throughout all the compartments placed in class A. The results are shown compartment by compartment in Appendix C.

Applying the factors given in paragraph 12 of the working plan report*

* The following table shows the contents of trees as calculated :—

Kind of tree.	WEIGHT OF FUEL IN MAUNDS OF 1,000 lbs.			
	1st class.	2nd class.	3rd class.	4th class.
Oak . . .	90	40	15	4
Chir . . .	85	52	21	7
Brons and ayar, etc.	35	18	$9\frac{1}{2}$	6

to the results obtained by the enumeration survey, the total available stock at present on the ground has been calculated as follows :—

Kind of trees.	Class.	Number of trees counted.	Contents in maunds of 100 lbs. per tree.	Total maunds of 100 lbs.
Tilonj	I	928	90	83,520
	II	1,366	40	54,640
	III	2,459	15	36,885
	IV	9,341	4	37,364
Banj	I	1,082	90	97,380
	II	1,342	40	53,680
	III	2,048	15	30,720
	IV	6,222	4	24,888
Ayar and brons	I	352	35	12,320
	II	695	18	12,510
	III	1,594	9½	15,143
	IV	2,866	6	17,196
Miscellaneous	I	787	35	27,545
	II	1,239	18	22,302
	III	2,697	9½	25,621
	IV	8,231	6	49,386
		Total available stock		601,100

The object to be attained is, whilst utilising to the full all that the forests are capable of yielding without deteriorating, to ensure the permanence of the forest estate, to enrich it, and bring it into a normal condition with all ages represented in due proportion, and in as complete a state as possible. In the better stocked portion of class A we shall be justified in utilising an amount of material approaching the annual production. In the poorly stocked areas of class B it must be our aim to preserve the existing stock most carefully, and to endeavour to encourage the growth of forest vegetation over places where it is at present absent.

The forests are naturally "high forests," reproducing themselves from seed, and when in a condition of completeness will yield the highest possible amount of material which the ground is capable of producing. The slopes are nearly everywhere steep, and the forests are much exposed to violent storms both of wind and snow; landslips are to be feared; and the method of "selection" or "jardinage" is certainly the most suitable to apply. We have seen however that there are a considerable number of injured individuals, damaged in

the past by various causes, found throughout these forests; also that in places the young oak poles are growing up so thickly as to be struggling with and interfering with each other. It will be therefore very desirable to arrange to replace such damaged stems by more healthy young growths, and to help the young oak trees where they are interfering with each other. At the same time then that the mature material may be removed by careful selection fellings improvement fellings of damaged stems combined with thinnings of young poles should be carried out as may be found advisable according to the conditions obtaining in the compartment under treatment. These operations are of a complicated nature; and the officer marking the trees should possess the technical knowledge necessary to carry them out properly. Coupes will be formed, and the amount of material which may be taken from each one will be fixed. From the compartments placed in class B no trees except dead and dying ones must be felled.

The oak being much the most important species, the exploitable age must be fixed with reference to it alone. Mr. Fernandez, in his working plan for the Naini Tal reserved and protected forests, notes that though the mean annual production of oak trees goes on increasing up to a considerable age, yet after attaining a girth of 5 feet at an age of about 120 years, they spread out their crowns to such an extent as to cause great damage to all young trees in their immediate vicinity. He therefore fixes the size at which oaks can be cut with most advantage at 5 feet in girth, and calculates the exploitable age to be 120 years. It is not, however, considered that we should be justified in accepting this conclusion. The theoretically true exploitable age is that at which the mean annual production is at its highest point. Mr. Fernandez's experiments gave results as follows :—

Girth.	Age.	Cubic contents.	Mean annual production.
	Years.		Cubic feet.
5′ 6″	120	67′	·55
6′ 6″	160	84′	·53
8′ 0″	205	139′	·67
9′ 9″	250	177′	·70
12′ 5″	330	221′	·66

The mean annual production appears therefore to be at its highest point when the tree has attained a girth of about 10 feet at an age of about 250 years. Sound trees of such a size are, however, very rare; taking poor and rich soils together, the trees appear to be mature at a size of about 6 feet 6 inches, and to deteriorate and become unsound after passing this girth. Moreover, it is probable that the old tree of 250 years of age, with its large spreading crown, will not be producing as much wood as the young growth which it prevents from occupying the ground underneath its cover would be. It is therefore considered that the most advantageous size to fell oak is 6 feet 6 inches, and the exploitable age is accordingly estimated to be 160 years.

The general working scheme is to undertake combined selection and improvement fellings throughout the compartments placed in class A, and by these fellings to remove the annual yield and no more. Ten years is proposed for the felling rotation. In this manner each coupe will have the benefit of nine

years' rest before fellings again pass through it, and the fellings which will remove ten times the annual production of the coupe will not be too heavy.

The total available stock now on the ground amounts to 601,000 maunds (100 lbs.) of fuel; the exploitable age has been estimated to be 160 years, and the mean age of the crop may therefore be considered to be 80 years. The annual production is then 7,500 maunds, and this is the possibility.* In this estimate no account has been taken of stems under 18 inches in girth. There are a great number of such; but they are in reality part of the future crop, not the present one, and by ignoring them we form a most necessary reserve, which will go to enrich the forests and render them more complete and valuable.

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ii.—The French Method.

This method was first introduced into France in 1883, and it has since then been applied to a large number of hill forests, treated under the selection system. The method is applied as follows:—

Firstly.—The diameter of the exploitable tree having been fixed, the trees standing in the forest are divided into 3 diameter classes, namely—

Class I = over $\frac{2}{3}$ of diameter of exploitable tree.
Class II = $\frac{1}{3}$ to $\frac{2}{3}$ ditto.
Class III = under $\frac{1}{3}$ ditto.

Secondly.—The proportion between the volume of material in Class I and Class II is ascertained. In a normally stocked forest this proportion should be as 5 : 3.† If this proportion does not exist it may be found possible to make suitable transfers from one class to another.

Thirdly.—The possibility is fixed by dividing the volume of material finally remaining in Class I (as amended) by $\frac{1}{3}$ of the number of years in the exploitable age.

As a precautionary measure, the increment which the Class I trees will lay on during the period for which the possibility is calculated (namely, $\frac{1}{3}$ of rotation) is omitted. Again, any fellings which it may be found necessary to make in the woods of Class II will count against the possibility, although no allowance for this has been made in calculating the annual yield.

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* *i.e.*, $\dfrac{601,100}{\frac{160}{2}} = 7,500$ maunds.

† *i.e.*, $\dfrac{\text{Volume of wood in Class I}}{\text{Volume of wood in Class II}} = \dfrac{\frac{\frac{2}{3}rv + rv}{2} \times \frac{a}{3}}{\frac{\frac{2}{3}rv + \frac{1}{3}rv}{2} \times \frac{a}{3}} = \dfrac{\frac{2}{3}+1}{\frac{2}{3}+\frac{1}{3}} = \frac{5}{3}$ (where a = area; r = exploitable age; v = mean annual increment per acre).

This method has now been in force in the vast majority of French selection forests for a period of a quarter of a century, and with excellent results. In the majority of cases, thanks to the degree of caution with which the possibility has been calculated (as above explained), the growing stock has improved, poorly stocked areas have become denser, and the mean girth of the stems has increased: though it is said that in some of the best forests, as a result of removing less than the true possibility, the growing stock has become over-mature, and over-dense.*

iii.—Fellings limited by Proportionate Volume.

This method of determining selection fellings by volume of material is based on the assumption that as in a high forest worked by the regular method, a definite proportion of the crop on the ground is always felled, so, in a selection-worked forest by invariably limiting the fellings to a certain percentage of the volume of the crop, the fellings may be kept within the possibility.

The method may be best explained by an example taken from D'Arcy's Preparation of Forest Working Plans in India, page 93:—

Applying the above theorem to a fairly homogeneous fir forest, containing a wooded area of 1,600 acres in which the average annual production or capability of the soil has been ascertained to be 63 cubit feet of wood per acre a year, and assuming that the forest is worked by the regular method on a rotation of 150 years, each acre would produce during the rotation $150 \times 63 = 9{,}450$ cubic feet, and the volume of wood at any time during this rotation would, on the whole area, be one-half of $1{,}600 \times 9{,}450$ or 7,560,000 cubic feet. Now, the area of the forest being 1,600 acres and the number of years in the rotation 150 years, the size of the annual *coupes* (the forest being worked by the regular method) would be $1{,}600 \div 150 = 10{\cdot}66$ or $10\frac{2}{3}$ acres, and the volume of material felled each year would be $10\frac{2}{3} \times 9{,}450$ cubic feet$=100{,}800$ cubic feet, or 1·33 per cent. of the total material in the whole forest.

Similarly, were the rotation reduced to 100 years, the volume of wood on the ground would be $(63 \times 100 = 1{,}600) \div 2 = 5{,}040{,}000$ cubic feet; while the material removed at each felling, made on an area of $1{,}600 \div 100 = 16$ acres, would still be $16 \times 63 \times 100 = 100{,}800$ cubic feet. In this case, 2 per cent. of the material on the ground would be felled.

Therefore in a high forest worked by the regular method, there is a fixed proportion, depending on the length of the rotation, between the volume of the material felled each year and the total volume of material or the wood capital of the forest. This proportion, following a general law, varies inversely as the length of the rotation; that is to say, it is higher as the rotation is shorter and *vice versâ.*

* An article by A. S. entitled "Possibilité des Futaies Jardinées" in No. 11, Vol. 47, (June 1908), of the Revue des Eaux et Forêt, should be consulted.

Let us suppose that it is wished to ascertain by the volumetric method the possibility of the fir forest of 1,600 acres, excluding blanks for which it has been ascertained that the productive power of the soil is 63 cubic feet of wood a year. Let us also assume that the exploitable size of the trees is 2 feet in diameter, and that it requires on an average 150 years for the trees to attain that dimension.

Under these conditions, the material on the ground being, as stated, $(150 \times 63 \times 1,600) \div 2 = 7,560,000$ cubic feet, and the size of the annual coupes being $1,600 \div 150 = 10\frac{2}{3}$ acres, there would be felled each year $10\frac{2}{3} \times 63 \times 150 = 100,800$ cubic feet of wood, or 1·33 per cent. of the total material on the ground. On the assumption that were the forest worked by the selection method, an equivalent yield could be obtained, it would be possible, without exceeding the capability, to fell 1·33 of the material on the entire area, or 13·3 per cent. of the material on one-tenth of the area, every ten years. We may suppose that number of years to be the interval between the successive fellings on the same area and the forest to be divided into 10 coupes, or we may take as many times 1·33 per cent. of the material as there are coupes or years in the interval between the successive fellings. Now the wood capital will be far from being exactly and evenly distributed over the forest; some of the compartments will be rich in material and some poor. Each year there would, however, be exploited successively in each coupe in its turn 13·3 per cent. of the material on the ground, without ever exceeding this figure, but so as to fell exactly 100,800 cubic feet of wood. If the 13·3 per cent. of the material in a coupe exceeded the allotted total volume of 100,800 cubic feet, the surplus would be left for the following year; if less, the volume prescribed would be made good from the next coupe. In this manner what was felled in a compartment would always bear a fixed ratio to what existed in that compartment; from the rich compartment more would be taken, from the poor less; while outturn could remain the same from year to year.

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iv.—Gurnaud's Method.

Gurnaud's Method need not be described here in detail, and for two reasons. In the first place the method has been fully set forth in its most favourable light by Mr. E. E. Fernandez, late Conservator of Forests, in his report on a tour in France.* In the second place the method has not worked satisfactorily, for it appears to have been abandoned in the various localities in which it was originally tentatively applied.

The following extract from Mr. Fernandez's report gives a sufficiently clear account of the method:—

The rotation for the fellings is fixed at 6, 8 or 10 years, never more, and the compartments of the forest are formed into as many groups of as nearly as practicable equal productive power. If the forest is large, several felling circles are constituted, and then it suffices to divide each felling circle into equal or nearly equal coupes, 6, 8 or 10 in number, according to the number of years in the rotation: inequalities in yield of the different circles then counterbalance

* Report on tour in France: The Gurnaud system of treating and working forests on the so-called *Methode de Controle*, by E. E. Fernandez, Conservator of Forests. Printed at the Government Central Press, Simla, 1897.

each other sufficiently. Thus ultimately each coupe becomes a compartment, just as in the *régime* of coppice.

The coupes are worked successively in the order in which they follow one another on the ground.

At the beginning of each rotation a complete enumeration survey is made of all the trees 20 centimeters (8 inches) and over in diameter. Every tree more than 17½ but less than 22½ centimeters in diameter is registered as being 20 centimeters in diameter; every tree more than 22½ but less than 27½ centimeters as one of 25 centimeters; and so on. The quantity of stem-wood in each of these diameter classes rising from 20 centimeters, 5 centimeters at a time, is then computed from the results obtained from the careful cubing of type stems; and then by addition the quantity of stem-wood in each of the three larger working diameter-classes (Classes II, III and IV) described above is obtained. Let this be respectively V_{ii}, V_{iii} and V_{iv}

We will suppose that the forest under consideration has been taken in hand for the first time, so that the rate of growth is not known. M. Gurnaud does not waste any time or energy in trying to ascertain it (a more or less insoluble problem under the condition which he postulates for the future working of the forest), but makes the fixing of the yield of the ensuing rotation a matter of pure discretion.

Here is his method. He assumes a certain moderate figure for the percentage at which the annual increase has been taking place during the immediately preceding 6, 8 or 10 years, as the case may be. Then with the help of these two figures, which we will designate respectively *r* and *n*, and of that expressing the standing stock of stem-wood ($V_{ii}+V_{iii}+V_{iv}=$say V_p) he obtains, by means of a simple interest sum, the stock of stem-wood existing *n* years ago, which quantity we will designate V_n

$$=\frac{100V_p}{100\ r\ n}$$

Hence the current annual increment during the past *n* years

$$=\frac{V_p-V_n}{n}=\frac{{}_rV_r}{100\ r\ n}$$

It will be observed that it would be more correct to apply the formula for compound interest, and also to take into account the produce removed during the period in question; but, as will be seen, M. Gurnaud's subsequent use of the increment is such that the rough and ready method of calculation just described gives him all he wants.

If the forest appears complete, the three working diameter-classes are well represented and V_p is large enough, he prescribes for the quantum of the annual fellings the full figure obtained as above for the current annual increment. But almost invariably one or more of the three hypotheses assumed are wanting, and he accordingly reduces the annual yield for the ensuing rotation to some fraction of that figure, two-thirds, one-half, one-third, one-fourth or even less.

At the end of the first rotation he makes a fresh enumeration survey on the same principle as before. For the first time now he can calculate exactly the mean annual increment during the past *n* years, for he knows the stock standing respectively at the commencement and at the end of that period and the quantity of material cut out in the meanwhile. This time again the condition of the stock may be so far removed from the normal sought as to require the yield during the second rotation being reduced as before. And indeed it may be a good many rotations before it is possible to adopt the full figure of the past mean increment. Nevertheless each successive rotation will find the stock nearer the normal state.

Thus far we have considered a forest that is to be brought into full production; but the above system of fixing the annual yield can be applied just as well and with the same degree of certainty to forests which have also to fulfil other purposes besides supplying wood. For instance, the given forest area may have also to furnish grazing for a certain number of head of cattle; the maximum amount of tree-growth that may be maintained without detriment to the production of the required amount of herbage being known, the annual yield will be less than, equal to or exceed the current increment, according as the existing amount of grazing is more than sufficient, just sufficient or insufficient.

The annual fellings are made in both stories of the crop operated upon. In the upper story, that formed by the three largest diameter-classes, they combine the nature of a regeneration felling and of a thinning, in the lower that of a thinning and of a cleaning. The lower story should be taken in hand only after the work has been finished amongst the trees above, as it is only then that the individuals to cut out or foster can be selected with certainty. Moreover, the felling of the overhanging trees invariably injures some of the good stems below, and the lower crop cannot evidently be touched until all fear of such injury is over. In operating in the lower crop there should be no hesitation in removing these injured stems, as well as all brushwood and spreading and defective growth, and in thinning out patches that are too dense. Nevertheless on the pretence of doing this last, promising patches of advanced growth ought not to be interfered with, as it is only advance growth which comes up in patches that is worth anything. In the case of species that coppice, the injured and defective growth, provided the stem is not too thick, should be carefully cut back in order to shoot up again. At the same time as the cutting is being proceeded with, well-placed young individuals should be encouraged to grow up rapidly and straight by means of judicious pruning of side branches, correcting of forked growth, pinching off of superfluous buds, snapping off a too-luxuriant branch and so on. It should be remembered that only a very few of the numberless individuals of the undercrop can be preserved until they reach exploitable size, and no special attention given to these few can ever be considered wasted labour.

Dead and fallen trees and those cut by offenders should be utilised at once, wherever found, and their volume deducted from the quota of the regular felling when this arrives in due time.

The chief objections to Gurnaud's method (defects which have led to its abandonment) may be briefly alluded to. Foremost among these may be mentioned the utter impossibility in practice of obtaining correct increment figures for a whole forest by re-enumerations carried out at intervals of 6 or 8 years. In an experimental sample plot such valuation surveys can be made with great accuracy, but in an ordinary enumeration survey carried out over large areas by the ordinary establishment, mistakes which may even amount to 4 per cent. are not uncommon, and the results obtained under Gurnaud's method would in consequence be wholly incorrect. Further, the personal element, whereby the "fixing of the yield is made a matter of pure discretion," enters too greatly into the final calculation of the possibility.

Part III.

CONDUCT OF THE FELLINGS.

1. Principal Fellings: Felling Rules.
2. Subsidiary Operations: Improvement Fellings.

PART III.

CONDUCT OF THE FELLINGS.

SECTION 1.—PRINCIPAL FELLINGS: FELLING RULES.

Whether the possibility is expressed by area, by number of trees, or by volume, it will be found necessary to clearly lay down the manner in which the marking of trees for felling is to be carried out. The conduct of the fellings is usually embodied in a set of rules, which will naturally vary with the local conditions to be found in the area dealt with. In addition, it is usual to indicate in the description of compartments the sylvicultural requirements of each portion of the area. In drawing up such rules the following rough draft may be found applicable to the special conditions prevailing in Indian high forests:—

(i) *General Rules.*

1. No sound tree under . . . .* feet in girth measured at breast height may be felled unless it shows signs of cessation of growth, overmaturity, unsoundness, or of other defects, which make it probable that it will never attain exploitable dimensions; and it should then only be felled if its retention is not indicated on sylvicultural grounds.

2. Sound trees of prescribed dimensions should not be felled sc close together as to cause large blanks.

3. Trees below the prescribed dimensions which are dead, hollow, stag-headed, or diseased may be marked for felling, but only under direct supervision. Or

When any tree shows signs of premature decay and its removal would, in the opinion of the executive officer, be advantageous, it may be felled even if it has not attained the prescribed dimensions.

4. Trees should not be felled when they stand over heavy grass without advance growth. Or

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* Here enter minimum girth of exploitable tree. This may vary for different parts of the forest, being reduced for localities where, owing to unfavourable conditions, trees are not expected to reach such large dimensions.

Isolated seed-bearers should on no account be felled unless there is sufficient crop of young growth on the ground, and it is desirable to clear away the cover from them.

5. Dead trees should be worked out along with the green trees marked on the areas.

NOTE.—In many cases the removal of dead trees from any portion of the forest is left to the discretion of the Conservator. Thus, in certain Central Provinces working-plans the following prescription occurs :—" The removal of dead and dying trees may be allowed in such places and under such circumstances as may be sanctioned by the Conservator."

But it should be prescribed whether dead trees of exploitable size are to count against the possibility or not.

(ii) *Special Rules.*

1. When the object of management, as for instance in the case of certain Burma teak forests, is to produce a certain amount of timber of large dimensions the following rule may be introduced :—

Sound vigorous trees if standing in localities from which they can be easily extracted should not be marked for felling unless they show signs of cessation of growth.

2. When, as in the Burma teak forests, girdlings are carried on in advance of the fellings, some prescription has to be introduced in order that the fellings may keep pace with the girdlings. The following rule may then be prescribed :—

The progress of girdlings in each sub-periodic block should be regulated by the progress of extraction of trees girdled during the previous sub-period, girdling operations being so controlled that marketable stems do not remain standing for more than 3 years after girdling.

3. It frequently happens that where systematic working is first introduced, and especially in the case of remote forests, the demand is not always sufficient to absorb the whole of the prescribed yield of the forest. In such cases, the following provisions taken from Mr. Morgan's Working Plan for the Motinala forests of the Mandla Division, Central Provinces, though not altogether sylviculturally correct, may be found useful :—

The annual coupe may be kept open for 2 years; after the expiry of that period, such portion thereof which, in the opinion of the Conservator, has not been fully worked over will be brought

forward as an unworked balance which will however be struck off from the control forms at the end of the fifth year.

In the event of a temporary excessive demand arising, which cannot be met from the area appointed for felling during the year, or from coupes of the five previous years which have not been fully worked over, it will probably be advisable to open one or more coupes in advance, or coupes against which an unworked balance has been struck off the control forms not more than 10 years previously, in order that advantage may be taken of such temporary demand in view not only of the financial benefit which would be derived, but also of the benefit to the forest of early working, and the Conservator will prescribe the manner in which the working is to be brought back within the lines of the plan.

Section 2.—Subsidiary Operations: Improvement Fellings.

Cultural operations for the improvement of the crop must always accompany selection fellings. Such improvement fellings cannot as a rule be defined with the same degree of exactitude as the similar operations required under other sylvicultural systems. Nevertheless, under Indian conditions, cleanings and climber cuttings, thinnings and cutting-back operations will always be found of the greatest importance in order to help natural regeneration and to improve the growth of the existing stock. Where trees of the principal species require freeing from too dense a canopy, or, in the case of larger-sized trees, where they are dominated by inferior trees growing beside them, improvement fellings must be made. All useless, quick-growing species hindering the growth of the superior species must be girdled, lopped, or felled, if necessary; creepers must be cut; epiphytic fici removed; broken, injured and badly shaped saplings and poles of the more valuable species must be coppiced in order that they may be replaced where this is required by new stems springing from the stool; young seedlings of the valuable species must be uncovered, their terminal buds being cleared by the removal of the heads or branches of the neighbouring plants; and wherever patches of congested pole growth are found, thinnings must be made.

The object of all such operations is to increase the proportion of the more valuable species in the crop, and to foster the existing young growth: but their nature and extent must always depend on

the kind of forest, the state of vegetation, the conditions of soil and climate, and the amount of funds and supervision available. In drawing up prescriptions under this head the following points should be attended to:—

(*i*) *Cleanings and Weedings and Cutting-back operations*—

1. Improvement fellings should either follow extraction or precede it by a sufficient time to allow the felled trees to decay and so not impede transport (wherever the sale of such produce cannot be effected); and they should be repeated as frequently as the circumstances of the case demand, taking into consideration funds and establishment available.

(*Note.*—As a general rule, improvement fellings should be carried out in each area as soon as possible after the major timber exploitations have been completed.)

2. Improvement fellings should be carried out by a trained officer, if possible.

(*Note.*—Forest Guards may be trained to do good work in this respect.)

3. Small seedlings of valuable species should be assisted by freeing them from bamboos and undergrowth, and superfluous shoots should be removed.

4. The crowns of healthy, well grown, promising, young poles and saplings of the principal species should be freed from all low overhead cover as far as possible.

5. Unsound trees of the principal species, and all trees of inferior species interfering with the growth of trees of superior species should (when unsaleable) be girdled, if girdling will kill them, and in the case of trees which will not die by girdling, should be felled.

But good trees of marketable species overshadowing or suppressing trees of the principal species should only be killed if the suppressed tree is likely to increase in value more than the tree or trees suppressing it, or if for sylvicultural reasons (*e.g.*, the production of seed), the suppressed tree is required.

6. All marketable dead and unsound trees, and trees badly damaged by main fellings, which are not likely to increase in value and are not required for seed may, if convenient to do so, be marked for extraction.

7. Badly grown and unsound poles which will produce good coppice shoots should be carefully cut flush with the ground, when such reproduction is required.

8. Improvement fellings are as a rule carried out solely with the object of favouring the development of promising young poles, and seedlings of the principal species. But in exceptional cases the intention may also be to induce reproduction where this is absent; and in that event improvement fellings may also be directed to the following points:—

(*a*) The removal of badly grown, low-spreading trees of the principal species, as well as those unsaleable from hollowness or defective growth, which are impeding possible natural reproduction from surrounding trees of the principal species.

(*b*) The removal of useless miscellaneous species with large low crowns, the shade of which is obviously preventing the reproduction of the principal species beneath them.

(*ii*) *Thinnings*—

Thinnings in young thickets of saplings and poles may be done at the same time as the regular selection markings are being carried out, or with the prescribed improvement fellings.

(*Note.*—Frequent light thinnings are better than heavy thinnings taking place at long intervals.)

(*iii*) *Climber Cuttings*—

All climbers should be cut in two places as far apart as possible. and the severed ends smashed with an axe to prevent coppicing.

(*Note 1.*—Climbers should be cut at the time the markings for fellings are being carried out, and at the time of felling; and the whole area may be gone over twice or oftener during the felling rotation.)

(*Note 2.*—Climber cutting can be carried out by Forest Guards.)

(*iv*) *Removal of Epiphytic Fici*—

1. All trees attacked by epiphytic fici should be felled at the time the regular selection markings are being carried out.

APPENDIX A.

Indian sanctioned working-plans relating to selection-worked forests classified according to the method of calculating the possibility.

Indian sanctioned working-plans relating to selection-worked forests,

Serial No.	Name of Province.	Name of Forest Circle.	Name of Forest Division.
			SELECTION SYSTEM—
1	United Provinces . .	Eastern Circle . .	Pilibhit . . .
2	" . .	" " . .	Gonda . . .
3	Bengal . . .	Bengal . . .	Singhbhum . . .
4	" . . .	" . . .	Tista . . . .
5	Eastern Bengal and Assam	Eastern Bengal and Assam	Sibsagar . . .
6	Central Provinces . .	Northern Circle . .	Mandla . . .
7	Coorg	Coorg	......
8	"	"	......
9	Burma . . .	Pegu Circle . . .	Rangoon . .

classified according to the method of calculating the possibility.

Name of Working-Plan.	Principal species dealt with.	REMARKS.
1. METHOD BY AREA.		
Surai-Banbasa forests .	Sâl (Shorea robusta) .	Trees of exploitable girth may be felled in any year, at any part of the area.
Tulsipur forests* . .	Sâl	Half the mature trees, *i.e.*, the more mature half, according to the girths fixed, may be removed.
Reserved forests of Singhbhum.	,, ...	Fellings limited by area. From each coupe all trees over 6 feet in girth may be removed.
Tista Division forests .	Sâl, Oak, Magnolias, Chestnut, Rhododendron, etc.	Fellings limited by area and sylvicultural requirements with minimum girth limit.
Nambor reserved forests .	Mesua ferrea, Vatica, Chinensis, etc.	Felling rotation = $\frac{1}{3}$ the time required for a tree of the second class ($4\frac{1}{2}'$) to reach the first class ($6'$). Possibility fixed by area. Only one tree of exploitable girth is to be removed.
Banjar valley forests .	Sâl	All first class trees and half of the second class trees may be marked for felling in each coupe. An eye estimate of the number of trees to be removed in each coupe is also given.
Anekadu-Attoor forests .	Teak, etc. . . .	Fellings limited by area. Only decaying and overmature trees to be removed.
Nalkeri-Hatgat forests .	,, ,, ...	Ditto.
Rangoon Plain forests .	Teak, and Xylia dolabriformis, etc.	Trees of exploitable girth may be removed over one-twentieth of area annually.

Indian sanctioned working-plans relating to selection-worked forests;

Serial No.	Name of Province.	Name of Forest Circle.	Name of Forest Division.
			SELECTION SYSTEM—2. POSSIBILITY BY
1	Punjab . . .	Punjab . . .	Rawalpindi . . .
2	,, . . .	,, . . .	Kangra . . .
3	,, . . .	,, . . .	Chamba . . .
4	,, . . .	,, . . .	,, . . .
5	,, . . .	,, . . .	Simla . . . .
6	North-West Frontier Province.	North-West Frontier Province.	Hazara . . . .
7	,, ,,	,, ,,	,, ...
8	United Provinces .	Western Circle . .	Jaunsar . . .
9	Eastern Bengal and Assam	Assam	Garo Hills . . .
10	,, ,, ,,	,, ...	,, ,, . . .
11	,, ,, ,,	,, ...	Goalpara . . .

classified according to the method of calculating the possibility.

Name of Working-Plan.	Principal species dealt with.	REMARKS.
NUMBER OF TREES.—i. BRANDIS' METHOD.		
Murree-Kahuta . .	Pinus longifolia. Pinus excelsa, Oak, and Deodar.	All Class I trees to be removed in time it takes to replace them.
Kangra Forest Division .	Pine, Oak, Fir and Deodar	One-third of Class I trees to be removed in time it takes to replace them.
Dalhousie Range forests	Deodar, Silver Fir, Spruce and Oak.	All Class I trees to be removed in time it takes to replace them.
Pangi leased forests .	Deodar, Blue Pine, Spruce and Silver Fir.	All Class I trees to be removed in time it takes to replace them.
Bashahr leased Sutlej Valley forests.	Deodar, P. excelsa, P. longifolia, Spruce, and Silver Fir.	All Class I trees, less 1 tree per acre, to be removed in time it takes to replace them.
Danggalli and Tandian ranges.	Pinus excelsa and Oak .	All Class I trees to be removed in time it takes to replace them.
Kagan range forests .	Deodar and Pine . .	All Class I trees to be removed in time it takes to replace them.
Tehri Garhwal leased deodar forests.	Deodar	All Class I trees to be removed in time it takes to replace them.
Dambu forests . . .	Sâl	A portion of Class I trees to be removed in time it takes to replace them.
Darugiri	,, ...	All Class I trees to be removed in time it takes to replace them.
Goalpara Sâl forests .	,, ...	Half the existing stock of Class I trees to be removed in one-third of the time required to replace them.

Indian sanctioned working-plans relating to selection-worked forests,

Serial No.	Name of Province.	Name of Forest Circle.	Name of Forest Division.
			SELECTION SYSTEM—2. POSSIBILITY BY
12	Central Provinces . .	Northern Circle . .	Mandla . . . .
13	,, . .	Southern Circle . .	Chanda . . . .
14	,, . .	,, ,, . .	Balaghat . . . .
			SELECTION SYSTEM—2.—POSSIBILITY BY NUM
1	Punjab . .	Punjab . . .	Kulu . . . . .
2	,, . .	,, . . .	Chamba . . . .
3	,, . . .	,, . . .	Simla . . . . .
4	North-West Frontier Province.	North-West Frontier Province.	Hazara . . . .
5	United Provinces . .	Western Circle . .	Sewalik . . . .
6	,, ,, . .	,, ,, . .	Ganges . . . .
7	,, ,, . .	,, ,, . .	,, ...
8	,, ,, . .	,, ,, . .	Garhwal . . . .
9	,, ,, . .	,, ,, . .	Naini Tal . . . .
10	,, ,, . .	,, ,, . .	,, ,, . . .

classified according to the method of calculating the possibility.

Name of Working-Plan.	Principal species dealt with.	REMARKS.
NUMBER OF TREES.—i. BRANDIS' METHOD—*continued.*		
Motinala range . .	Sâl	All Class I trees, unsound, mature or languishing Class II trees, and unsound Class III trees to be removed in time it takes to replace Class I trees.
Allapilli forests . .	Teak, etc.	All Class I trees and unsound Class II trees.
Topla-Kuilikhapa forests	Sâl	All Class I trees to be removed in time it takes to replace them.
BER OF TREES.—ii. OUDH METHOD.		
		Number of trees brought into the possibility:—
Kulu forests	Deodar, P. longifolia, P. excelsa, Spruce and Silver Fir.	All Class I trees + $\frac{1}{4}$ Class II trees.
Upper Ravi forests .	Deodar, P. excelsa, Spruce and Silver Fir	All Class I trees + $\frac{1}{4}$ Class II trees.
Reserved forests of the Jubal State.	P. excelsa, Deodar, Spruce and Silver Fir.	All Class I trees + $\frac{1}{5}$ Class II trees.
Siran Range forests .	Deodar or Pines . .	All Class I trees + $\frac{1}{3}$ Class II trees.
Dehra Dun forests (revised).	Sâl, etc.	All Class I trees + $\frac{1}{2}$ sound Class II trees which it is considered will never mature.
Ganges Forest Division .	,, ...	All Class I trees + $\frac{1}{4}$ Class II trees.
Lansdowne reserved forests	,, ...	All Class I trees + a proportion of Class II trees.
Garhwal Forest Division .	,, ...	All Class I trees + $\frac{1}{4}$ Class II trees.
Naini Tal Cantonment forests.	Oak and P. longifolia .	All Class I trees + $\frac{1}{10}$ Class II trees.
Naini Tal Municipal forests	,, ,, .	Half Class I trees + $\frac{1}{5}$ Class II trees.

Indian sanctioned working-plans relating to selection-worked forests,

Serial No.	Name of Province.	Name of Forest Circle.	Name of Forest Division.
			SELECTION SYSTEM—2. POSSIBILITY BY NUM
11	United Provinces . .	Eastern Circle .	Kumaun . . .
12	Bengal	Bengal . . .	Kurseong . . .
13	Eastern Bengal and Assam	Eastern Bengal and Assam	Buxa . . . .
14	Lower Burma . .	Pegu Circle . .	Tharrawaddy . . .
			SELECTION SYSTEM—2. POSSIBILITY BY NUM
1	United Provinces . .	Western Circle . .	Naini Tal . . .
2	„ „ . .	„ „ . .	„ „ . . .
3	„ „ . .	„ „ . .	„ „ . . .
4	„ „ . .	„ „ . .	„ „ . . .
5	„ „ . .	Eastern Circle . .	Kheri . . .
6	Burma	Pegu Circle . .	Tharrawaddy . . .
7	„	„ „ . . .	„ . . .
			SELECTION SYSTEM—2. POSSIBILITY BY NUM
1	Punjab . . .	Punjab	Simla . . . .
2	United Provinces . .	Western Circle . .	Jaunsar . . .

classified according to the method of calculating the possibility.

Name of Working-Plan.	Principal species dealt with.	REMARKS.
BER OF TREES.—ii. OUDH METHOD—*continued.*		
Kumaun Forest Division	Sâl, etc. . . .	All Class I trees + ¼ Class II trees.
Reserved forests of Kurseong Division.	,, . . .	All Class I trees + ½ Class II trees.
Reserved forests of Buxa Division.	,, . . .	All Class I trees + such proportion of Class II trees as have reached the exploitable size when felling area is worked over.
Thonze Reserve . .	Teak . . .	All Class I + Class II trees.
BER OF TREES.—iii. GENERAL POSSIBILITY METHOD.		
Naini Tal Sub-Divisional forests.	P. longifolia, Oak, Sâl, etc.	
Ranikhet Sub-Divisional forests.	,, ,, etc. .	
Ranikhet Cantonment forests.	,, ,, ,, .	
Muktesar Reserved forests	Oak, P. longifolia, etc. .	
Trans-Sarda forests .	Sâl, etc. . . .	
Minhla forest . .	Teak, Xylia dolabriformis, etc.	
Gamon forest . .	,, ,, ,, .	
BER OF TREES.—iv. BURMA METHOD.		
Kotkhai and Kotguru reserved forests.	Deodar, Pines, Spruce, etc.	Stock of surplus trees is below number required to work up to full possibility.
Government forests in Jaunsar-Bawar.	Deodar, Oak, Spruce, Silver Fir, etc.	Possibility calculated for whole period of rotation.

Indian sanctioned working-plans relating to selection-worked forests,

Serial No.	Name of Province.	Name of Forest Circle.	Name of Forest Division.
			SELECTION SYSTEM—2. POSSIBILITY BY NUMBER
3	Lower Burma .	Pegu Circle . . .	Thayetmyo . . .
4	,, ,, . .	,, ,, . . .	Rangoon . . .
5	,, ,, . .	,, ,, . . .	,, . . .
6	,, ,, . .	,, ,, . . .	Tharrawaddy . .
7	,, ,, . .	,, ,, . . .	,, . .
8	,, ,, . .	,, ,, . . .	,, . .
9	,, ,, . .	,, ,, . . .	,, . .
10	,, ,, .	,, ,, . . .	Prome . . . .
11	,, ,, . .	,, ,, . . .	,, . . .
12	,, ,, . .	Tenasserim Circle . .	Toungyo . . .
13	,, ,, . .	,, ,, . .	,, . . .

classified according to the method of calculating the possibility.

Name of Working-Plan.	Principal species dealt with.	REMARKS.
OF TREES.—iv. BURMA METHOD—*continued.*		
East Yoma, Satsuwa and Tindaw reserves.	Teak, Xylia dolabriformis, etc.	Possibility calculated for 32 years or $\frac{1}{5}$ of exploitable age.
South Zamayi Reserve .	,, ,, ,,	Possibility calculated for 30 years = $\frac{1}{5}$ of felling rotation.
Rangoon Hill forest .	,, ,, ,,	Possibility calculated for 30 years or = $\frac{1}{5}$ of felling rotation and removal of surplus trees spread over 2 periods.
Satpok, Sitkwin and Thindawyo reserves.	,, ,, ,,	Possibility calculated for 30 years = $\frac{1}{4}$ of exploitable age.
Kangyi forests . .	,, ,, ,,	Possibility calculated for 30 years = $\frac{1}{4}$ of exploitable age.
Bawbin Minbu reserves .	,, ,, ,,	Felling rotation arbitrarily fixed at 30 years; and possibility calculated for that period.
Taungnuyo forests . .	,, ,, ,,	Possibility calculated for 57 years, the period taken for a tree of the lowest dimensions of Class II to attain the lowest exploitable dimensions.
Nawin forests . .	,, ,, ,,	Possibility calculated for 30 years = $\frac{1}{5}$ of exploitable age, surplus stock removed in 2 felling rotations.
Shweli forests . .	,, ,, ,,	Possibility calculated for 30 years = $\frac{1}{5}$ of exploitable age. Surplus stock removed in 2 felling rotations.
Bondaung reserves .	,, ,, ,,	Possibility calculated for 30 years = $\frac{1}{5}$ of exploitable age.
West Swa, Sabyin and Lonyan reserves.	,, ,, ,,	Possibility calculated for 32 years = $\frac{1}{4}$ of exploitable age.

Indian sanctioned working-plans relating to selection-worked forest,

Serial No.	Name of Province.	Name of Forest Circle.	Name of Forest Division.
			SELECTION SYSTEM—2. POSSIBILITY BY NUMBER
14	Lower Burma . .	Tenasserim Circle . .	Toungyo . . .
15	" " . .	" " . .	" . . .
16	" " . .	" " . .	" . . .
17	" " . .	" " . .	" . . .
18	" " . .	" " . .	" . . .
19	" " . .	" " . .	Shwegyin . . .
20	Upper Burma . .	Southern Circle . .	Ruby Mines . . .
21	" " . .	" " . .	Pyinmana . . .
22	" " . .	" " . .	" . . .

classified according to the method of calculating the possibility.

Name of Working-Plan.	Principal species dealt with.	REMARKS.
OF TREES.—iv. BURMA METHOD—*continued.*		
Saing Working Circle .	Teak, Xylia dolabriformis, etc.	Possibility calculated for 30 years $= \frac{1}{5}$ of exploitable age.
Pyu-Chaung and Pyu-Kun reserves.	,, ,,	Possibility calculated for 33 years $= \frac{1}{5}$ of exploitable age.
Gwethe reserve . .	,, ,,	Possibility calculated for 30 years $= \frac{1}{5}$ of exploitable age.
Kabaung reserve . .	,, ,,	Possibility calculated for 30 years, the time required for a tree of the lowest dimensions of Class II to attain to the lowest dimensions of Class I. Removal of surplus stock spread over two felling rotations.
Kyaukmasin reserves .	,, ,,	Possibility calculated for 28 years $= \frac{1}{7}$ of exploitable age. Yield so calculated considerably reduced for reasons given.
Nyaunglebin Working Circle.	,, ,,	Possibility calculated for 30 years $= \frac{1}{6}$ of exploitable age.
Nanhan, Nanpaw and Subok reserves.	,, ,,	Possibility calculated for 30 years $= \frac{1}{6}$ of exploitable age. Removal of surplus stock spread over 2 periods.
Ngalaik reserves . .	,, ,,	Possibility calculated for 30 years; but yield so calculated considerably reduced for sylvicultural reasons.
Ziyaing Mehaw reserves .	,, ,,	Possibility calculated for 20 years$= \frac{1}{10}$ of exploitable age. Yield so calculated slightly reduced.

Indian sanctioned working-plans relating to selection-worked forests

Serial No.	Name of Province.	Name of Forest Circle.	Name of Forest Division.
			Selection system—2. Possibility by number
23	Upper Burma . .	Southern Circle . .	Pyinmana . . .
24	" " . .	" " . .	" . . .
25	" " . .	" " . .	" . . .
26	" " . .	" " . .	" . . .
27	" " .	" " .	" . . .
28	" " . .	" " . .	" . . .
29	" " . .	" " . .	" . . .
			Selection system—3. Possibility by volume.—
1	United Provinces . .	Western Circle . .	Naini Tal . . .

classified according to the method of calculating the possibility.

Name of Working-Plan.	Principal species dealt with.	REMARKS.
OF TREES.—iv. BURMA METHOD—*concluded.*		
Yeni reserve . .	Teak, Xylia dolabriformis, etc.	Possibility calculated for 30 years $=\frac{1}{5}$ of exploitable age. Removal of surplus stock spread over 2 periods.
Taungnyo reserve . .	,, ,,	Possibility calculated for 30 years $=\frac{1}{5}$ of exploitable age. Yield so calculated considerably reduced.
Minbyin reserve . .	,, ,,	Possibility calculated for 30 years $=\frac{1}{6}$ of exploitable age.
Pozaungdaung reserve .	,, ,,	Possibility calculated for 40 years = length of felling rotation.
Sinthe reserve . .	,, ,,	Possibility calculated for 32 years $=\frac{1}{5}$ of exploitable age. Yield so calculated considerably reduced.
Yonbin reserve . .	,, ,,	Possibility calculated for 30 years $=\frac{1}{5}$ of exploitable age. Removal of surplus stock spread over 2 periods.
Yanaungmyin, Kaing and Palwe reserves.	,, ,,	Possibility calculated for 30 years $=\frac{1}{5}$ of exploitable age. Removal of surplus stock spread over 2 periods.
i. MASSON'S OR VON MANTEL'S METHOD.		
Naini Tal Municipal Forests.	Oak, Pinus longifolia .	

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